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Radio Telemetry Studies of Arctic Grayling Migrations to Overwinter, Spawning and Summer Feeding Areas in the Parsnip River Watershed 1996-1997

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April 2002

PWFWCP Report No. 263

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ABSTRACT

The objective of this project was to track the movements of Arctic grayling (*Thymallus arcticus)* in the Table and Anzac rivers to wintering and spawning areas. In order to accomplish this, 55 Arctic grayling were captured by angling, surgically implanted with radio transmitters and released back into the Table and Anzac rivers. Table River fish moved downstream to overwintering areas in the Parsnip River by September 24, while Anzac fish remained near the tagging sites. The Anzac fish moved to overwintering areas by November 6th. The fish were tracked on a monthly basis throughout the winter. Overwintering locations were marked and habitat parameters were evaluated the following summer. Movements to overwinter areas averaged 55 km downstream with a range of 34 to 80 km. Selection of overwintering areas was not exclusively deep slow pool habitat, as many fish were found in shallow higher velocity areas. The initiation of migrations to spawning areas coincided with rising water temperatures and ice break up in late April. High flow and turbid water made the observation of spawning activities impossible. Based on water temperatures and fry emergence dates, spawning is believed to have occurred during the high flow period from late May to mid June. The average movement to spawning areas was 33 km with a range of 9 to 71 km. Many of the grayling moved to the multi channelled areas of the mainstems of the Parsnip and Anzac rivers during the spawning period. The males moved to the suspected spawning areas first and remained at one location for nearly one month. Some females moved slowly upstream during the spawning period, while others remained at one location. One third of the fish were not located in the stream where they had been tagged, during the spawning period. Once spawning was completed in late June the grayling moved to summer feeding areas and most of the fish moved back to the areas where they were tagged the previous year. Grayling started moving to overwintering areas by early October. The average movement over the one year period was 126 km with a range of 67 to 245 km.

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INTRODUCTION

Arctic grayling (*Thymallus arcticus)* populations in the upper Peace River Watershed declined dramatically during the early 1980's. Populations have disappeared from a minimum of 24 streams entering Williston Reservoir (Blackman and Langston 1992, Northcote 1993). There are still viable Arctic grayling populations in several of the larger and more remote systems but nearly all stocks utilising small to medium sized systems, flowing directly into the reservoir, have disappeared. In response to the decline in Arctic grayling stocks the Ministry of Environment Lands and Parks has designated the species as "red listed" (QS1 Conservation Data Centre) or critically imperilled within the watershed, and has imposed catch and release regulations.

A number of studies on Arctic grayling (Bruce and Starr 1985, Barrett and Halsey 1985, Blackman 1992, Blackman and Langston 1992, Langston and Blackman 1993, Langston 1998, Zemlak and Langston 1998 and Mathias et al 1998) have been conducted in this watershed. These studies identify the declining stocks, and document population characteristics and habitat utilisation. Minimal information is available on the locations of spawning areas and habitats, early rearing areas and migratory patterns of the remaining stocks in the watershed. The determination of what habitats are used for spawning and early rearing, which is suspected to be a very vulnerable life stage of Arctic grayling (Vincent 1963), is essential so that more effective habitat protection and restoration programs can be developed. In order to prevent further declines of the remaining Arctic grayling stocks, it is imperative that these critical habitats are identified in all systems and protected from negative impacts.

The purpose of this study was to determine migratory patterns, overwinter distribution and habitats, and spawning areas and habitats of Arctic grayling from the Table and Anzac Rivers. This project is a key element in a larger program to conserve and restore Arctic grayling stocks and habitat in the watershed.

Study Area

The Table and Anzac rivers are adjacent drainages, both tributary to the Parsnip River, which flows into Williston Reservoir and the Peace River. The Parsnip River (Fig 1), provides habitat for the southernmost distributions of Arctic grayling in British Columbia and is175 km in length and has a drainage area of 4,669 km^2,

The Table River (54°42' 122°17') and Anzac River (54°48' 122°32') watersheds are located approximately 100 km north of Prince George, B.C. (Fig 1). This drainage is in the Central Canadian Rocky Mountains Ecoregion and the Hart Range Ecosection. Watersheds in this area receive abundant rainfall, 55 to 191 cm annually (MacKinnon et al 1990). These rivers flow out of the Rocky Mountains, have steep valley walls and portions of the drainages are alpine in nature. The physical characteristics of these streams are very similar but the Anzac is in a relatively pristine state, whereas the Table River has been seriously impacted by industrial activities such as logging, roads and railroad track construction.

The Table River drains a watershed of 506 km^2 (Fig 1) and is 56 km in length with an average gradient of 0.7 %. The upper reaches (3-7) have a moderate gradient (1-2%) and are frequently confined. Reaches one and two are low gradient (<0.5%) and are unconfined on the 1 to 2 km wide valley flats. They have tortuous meanders with many old ox bows, side channels, and

abandoned channels. Reach one and the lower section of reach two flow through an area of fluvial silt deposits and as a result bank stability is poor. There is a high percentage of fines in the substrate. Nearly 40% of the stream channel has been logged up to or in the riparian zone (Mathias *et al.* 1998). A railroad line, built by B.C. Rail in the late 1970's to service the Tumbler Ridge Coal Development Project, runs along the majority of the length of the river. Railway construction probably had severe impacts on fish production in the system because of extremely heavy silt loads and slide activities in the upper watershed. This continued for a period of four to six years during the early 1980's (D. King, Pers comm. Habitat Section Head, Ministry of Environment Lands and Parks, Prince George, B.C.)

The Anzac River (54°48' 122°32') drains a 939 km^2 watershed and is 78 km in length with an average gradient of 0.7%. Reach four is a bedrock canyon with a moderate gradient (1-2%). Reaches one and two have a low gradient (<0.5%), and are unconfined on one to two km wide valley flats. They are similar to the lower Table River with tortuous meanders, old ox bows, side channels and abandoned channels. Reach two is multi-channelled and has some areas with fluvial silt deposits. The substrate of Reach one is composed of more gravels and cobbles with fewer fines than in the Table River and bank stability is good. The lower valley flats were logged in the 1940's, but have successfully grown back (Mathias *et al.* 1998). Both systems have barriers (km 47of the Anzac and km 37 of the Table), which block Arctic grayling access to the upper watershed.

There are no historical stream flow records for the Table or Anzac rivers, although a flow gauge station was installed on the Anzac River in 1997. Flow records are available for the Parsnip River, (gauge located on the lower river) which had a mean daily flow rate of 142 m^3/sec for the period from 1985 to 1995. During this period the average, maximum daily flow rate was 824 m^3/sec and the minimum was 23 m^3/sec. The highest flows occur in late May, and the lowest flows occur during the period from September to March. Spring break-up usually occurs in April and ice over occurs in November (Water Survey of Canada).

Fish species identified in the Table, Anzac and Parsnip rivers include: Arctic grayling (*Thymallus arcticus*), bull trout (*Salvelinus confluentus*), rainbow trout (*Oncorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), lake whitefish (*Coregonus clupeaformis*), burbot (*lota lota*), northern pikeminnow (*Ptychochelus oregnensis*), largescale suckers (*Catostomus macrocheilus*), longnose suckers (*Catostomus catostomus*), white suckers (*Catostomus commersoni*), slimy sculpins (*Cottus cognatus*), prickly sculpins (*Cottus asper*) and longnose dace (*Rhinichthys cataractae*) (Anonymous 1978).

METHODS

The 1996 and 1997 Table/Anzac Arctic grayling program consisted of three phases: radio tag implantation, the tracking of tag movements and habitat assessment. The following sections explain the methodologies used in each phase.

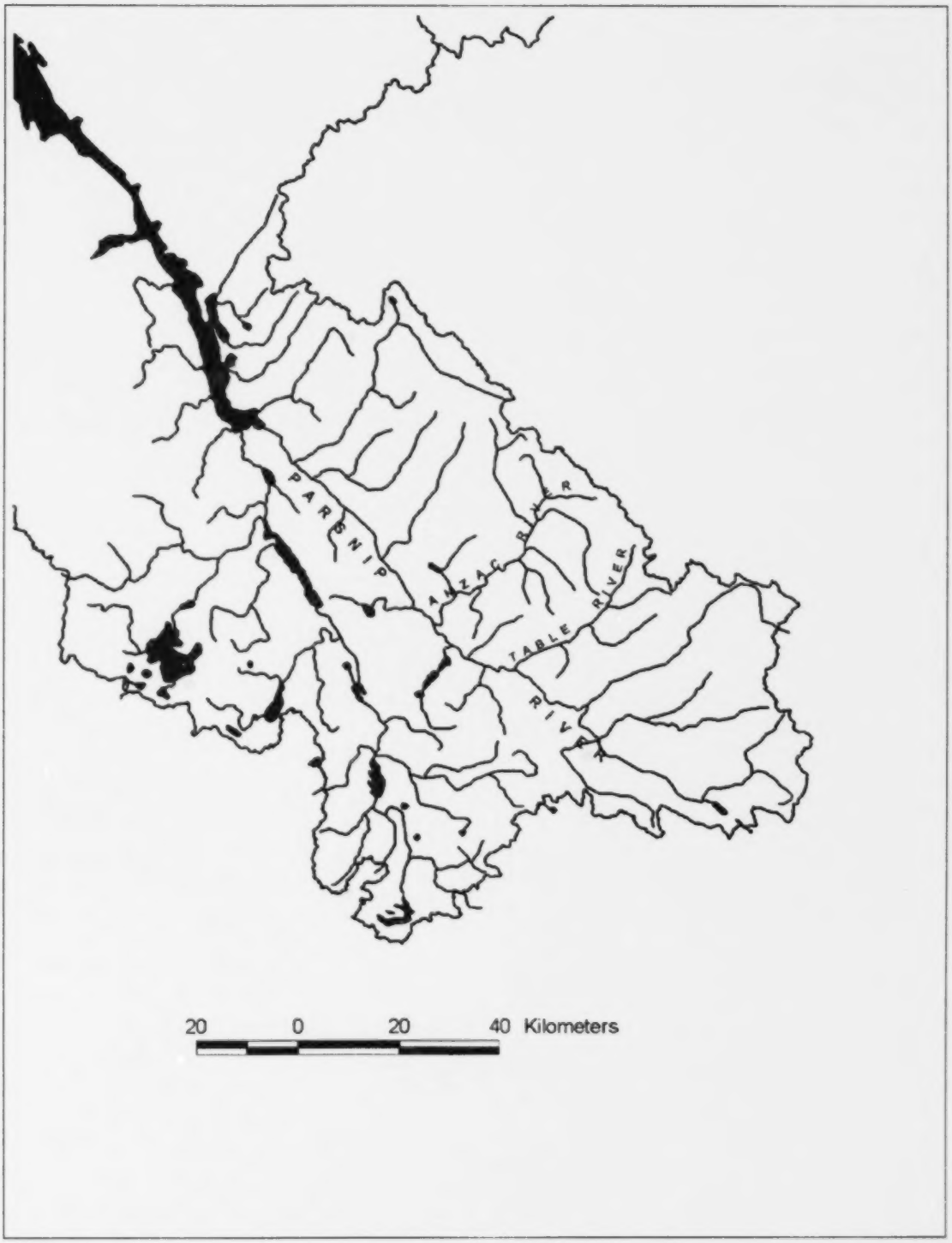


Figure 1. Study area of the grayling radio telemetry project

Radio Tag Implantation

Fish capture and holding

Arctic grayling were captured by angling, during the period from August 22 to September 6 1996. Uninjured fish were allowed to recover from being angled for 5 to 20 minutes before surgery in either large plastic coolers filled with river water or in recovery tubes. The recovery tubes were constructed from 10x70 cm PVC pipe with removable end caps and multiple 2.5 cm holes for water circulation, which were positioned in shallow, moderate velocity areas of the river.

Site Selection

All radio tagged fish were released at the capture sites. Efforts were made to evenly distribute the radio tagged fish throughout the streams, (Fig 2) but very few grayling large enough to tag (>385 g) were captured in the mid or lower sections of the rivers. In order have radio tagged fish from the mid and lower sections, some smaller grayling were implanted (Appendix A). No more than three fish were implanted at a location (except one site), although some sites were only a few hundred meters apart. Most tagging sites were reached by helicopter or boat. Sites near road access were avoided.

Anaesthetic

Clove oil was mixed with ethanol in a 1:10 ratio and 4.4 ml of the solution were added to a cooler, which contained 10 litres of river water, to produce a 40 ppm solution of anaesthetic (Blackman 2002). The solution was prepared fresh each day to reduce oxidation of the clove oil and fresh anaesthetic was used at each site as recommended by Dr. S. McKinley (pers comm, Univ. of Waterloo, Anderson et al. 1997). A low concentration (5-10 ppm) of anaesthetic was washed over the gills and eyes of the fish during the surgery. The wash was applied from a ten litre plastic water bottle equipped with a spout, shut off and 1 meter of surgical tubing.

Surgery

The radio tags were surgically implanted using the methodologies outlined by McKinley et al (1992) and Blackman (in prep). The timing of the tagging (Aug 22 to Sept 6) was calculated to allow the fish to heal from surgery before water temperatures dropped, which would slow the healing process (Dr. S. McKinley, Univ. of Waterloo, pers comm).

Surgery consisted of the following procedure:

- a three cm incision was made three to four cm from the mid ventral line anterior to the pelvic fins ;
- a hollow needle was inserted through the body wall posterior to the incision and the transmitter antenna was threaded out through the centre of the needle;
- the transmitter (11 x43 mm , 7.7 g) was inserted into the body cavity and then pulled backward by the antenna;
- the incision was then closed using three to four permanent independent sutures;
- surgical instruments were washed with alcohol between implantations to provide a more sterile procedure.

No antibiotics, fungicides or other chemicals were used because of Provincial Fish Health Policies forbid the use of most chemicals on fish that are released into the wild at the time of this work (Prov of B.C. Procedure manual "Use of Drugs and Chemicals on Live Fish).

Tags

The tags used were Lotek model MCFT-3BM dimensions 11 x 43 mm, weight 7.7 g in air or 3.7 g in water. This weight of tag (7.7g) should be implanted into fish greater than 385 g to meet the 2% rule (Winter, 1983). The tags were programmable, operated on four frequencies (149.380, 149.560, 149.580 and 149.800 Hz) with 13 or 14 tags per frequency and individual tags were coded

(1-55). The transmission cycles were slightly offset so that if several fish were at the same location and transmitting on the same frequency they could be separated. Typical reported operational life for these tags was 260 days. This was insufficient for the purposes of this study, therefore, the tags were programmed by the manufacturer to transmit once every five seconds (rather than the standard once per second) and for only eight hours (9 am to 5pm) each day to increase the operational life of the tags.

Fish Sampling

All fish were measured to the nearest millimetre fork length and weighed using an electronic balance to the nearest gram. Fish that were too large to weigh (>400 g) on the balance were weighed to the nearest ounce, using an electronic scale and the data was converted to grams. Scale samples were taken for age verification and tissue (adipose fin) samples were collected for genetic analysis to support a related study. All fish were marked using individually coded "floy" tags. The sex of the fish was determined by the size of the dorsal fin (males have much larger dorsal fins, Scott and Crossman 1973) or by gonadal examination during surgery.

Release

After surgery and sampling was completed the fish were placed in the river to revive in small pens constructed from river rocks. The fish were held upright and gently moved back and forth to increase water flow over the gills until they were able to maintain an upright position. The fish remained in the pens until they appeared to have fully recovered and could swim upstream out the pen. Care was taken not to release fish until they had fully recovered to reduce potential predation by large bull trout. Large bull trout can be voracious predators (McPhail and Baxter 1995) and have attacked radio tagged kokanee in this watershed (Fielded 1992). Efforts were made to capture and hold any large bull trout in the area, before any grayling were released.

Underwater surveys were conducted on September 19 and 24, to verify the conditions of the tagged fish. Fish were located (via the radio tag) from a helicopter, and then pinpointed from the ground and two swimmers using snorkel gear and drysuits attempted to locate the fish.

Radio Tracking

Schedule and equipment

Tracking flights were conducted on a monthly basis throughout the winter to identify overwinter locations and on a biweekly basis in April once migrations had started. The frequency of the flights was increased to weekly during the suspected spawning period (May and June) and then to a monthly basis until October. Tracking flights were conducted using an A Star or Bell Jet Ranger helicopter which was equipped with an "H" (two element Yagi) antenna facing forward and a four element "Yagi" directional antenna facing downward at a 60° angle. The receiver used was a Lotek model SRX_400. The receiver was programmed to scan each frequency for 5.2 seconds and could be fixed on one frequency or a frequency could be dropped from the scan. Individual tag codes could not be fixed or dropped.

Procedures and location

Tracking flights were conducted at a speed of approximately 80 kph and an elevation of 100 meters above the stream using the "H" antenna until a signal (an audio "beep") was received and then the helicopter speed and elevation was decreased. When the signal became strong enough the frequency, tag code and signal strength appeared on the receiver display. The receiver operator would then isolate that frequency and switch from the "H "antenna to the "Yagi" to pinpoint the tag location. Using the signal strength readings, the position of the tag was determined and the Global Positioning System (GPS) location recorded, along with the tag code and signal strength and any pertinent comments. During different flights various GPS units were used to obtain the

location co-ordinates. A Trimble Geo Explorer 1 was used on Feb 19 th and the data post processed to give ± 1m accuracy for overwinter locations, a Trimble Flightmate was used to provide ground and flight locations and the Apollo II unit (helicopter unit) was utilised on other flights. These data were accurate to roughly ± 100 m. In addition to GPS co-ordinates, overwinter locations were photographed, and if it was possible to land the helicopter nearby, sites were marked on the banks with flagging tape.

Spawning Date / Location Verification

After the water levels receded in early July ground surveys were conducted and newly hatched grayling fry were found at many locations. The spawning period was calculated by estimating the emergence date, based on water temperature, known fry growth rates of 0.37 mm / day/ thermal unit @12 °C for hatchery fish,(Doug Popack, Fish and Game Dept, Calgary Alberta pers comm) reduced to 0.30 mm / day to compensate for the less than ideal conditions, an estimated hatch size of 12 mm, and a capture size of 16 mm. Spawning dates were then calculated based on an incubation period of 128 to 158 degree days (Don Bee Ft. Richardson Hatchery Alaska and Doug Popack, Fish and Game Dept, Calgary Alberta pers. comm.) and water temperature data obtained from a Ryan recording thermograph in the Table River.

Movement Calculations

The Table and Anzac rivers are very dynamic systems with many multi-channel sections and active channel movements. Fish movements were calculated by mapping the fish locations using GPS co-ordinates on a 1:175,000 map, based on the B.C. Provincial Watershed Atlas. The distance to tributary mouths from the stream mouth were marked on the map according to the B.C. Provincial Watershed Atlas. Distances between these points were interpolated. Tag locations were recorded on the maps to the nearest kilometre. Fish movements were calculated between these points. Fish were deemed to have died if the transmitter signal did not move after two months or during a period when other fish were showing movement. Fish that never showed upstream movements were also considered to have died.

Overwinter Habitat

Overwinter habitat utilisation sites were identified by radio tag positions during the December 16, February 19 and March 25 flights. Only sites occupied by fish that returned to spawning areas were included for overwinter habitat surveys. Sites were referenced using photographs taken from the air or from points marked on the ground. These sites were marked as accurately as possible, but frequently it was impossible to document an exact location of the fish. Site evaluations were conducted from September 30 to October 3,1997, to determine the types of habitats selected for overwintering. River cross sections of water depth, velocity, substrate and position of the thalweg were measured on transects both up and downstream from the estimated overwintering positions. Water depths were measured using a 4 meter measuring stick marked off in 0.1 m gradations and water velocities were measured using a Swoffer 2100 series flow meter (accurate to ±1%). Velocity measurements were taken just below the stream surface and 20 cm above the stream bottom. Wetted width and distance from shore was measured (±1m) using a Bushnel laser rangefinder. Substrate was recorded as silt, sand, gravel, cobble or boulder and was determined by visual observations in shallow water or by "feel" with the measuring stick in deeper waters, where visibility prevented detailed observations.

RESULTS

Tag Implantation

Twenty five Arctic grayling were captured, tagged (codes 1-25), sampled and released back into the Table River (Fig 2). The average fork length of the tagged grayling was 330 mm with a range from 300 to 354 mm. The average weight was 386 g with a range from 261 to 532 g. The average age of the tagged fish was 4.9 years with a range from 4 to 7 years.

Thirty Arctic grayling were captured, tagged (codes 26-55) and released back into the Anzac River (Fig 2). The average fork length of the tagged fish was 344 mm with a range from 312 to 380 mm. The average weight was 449 g with a range from 313 to 610 g . The average age was 5.3 years with a range from 4 to 7 years.

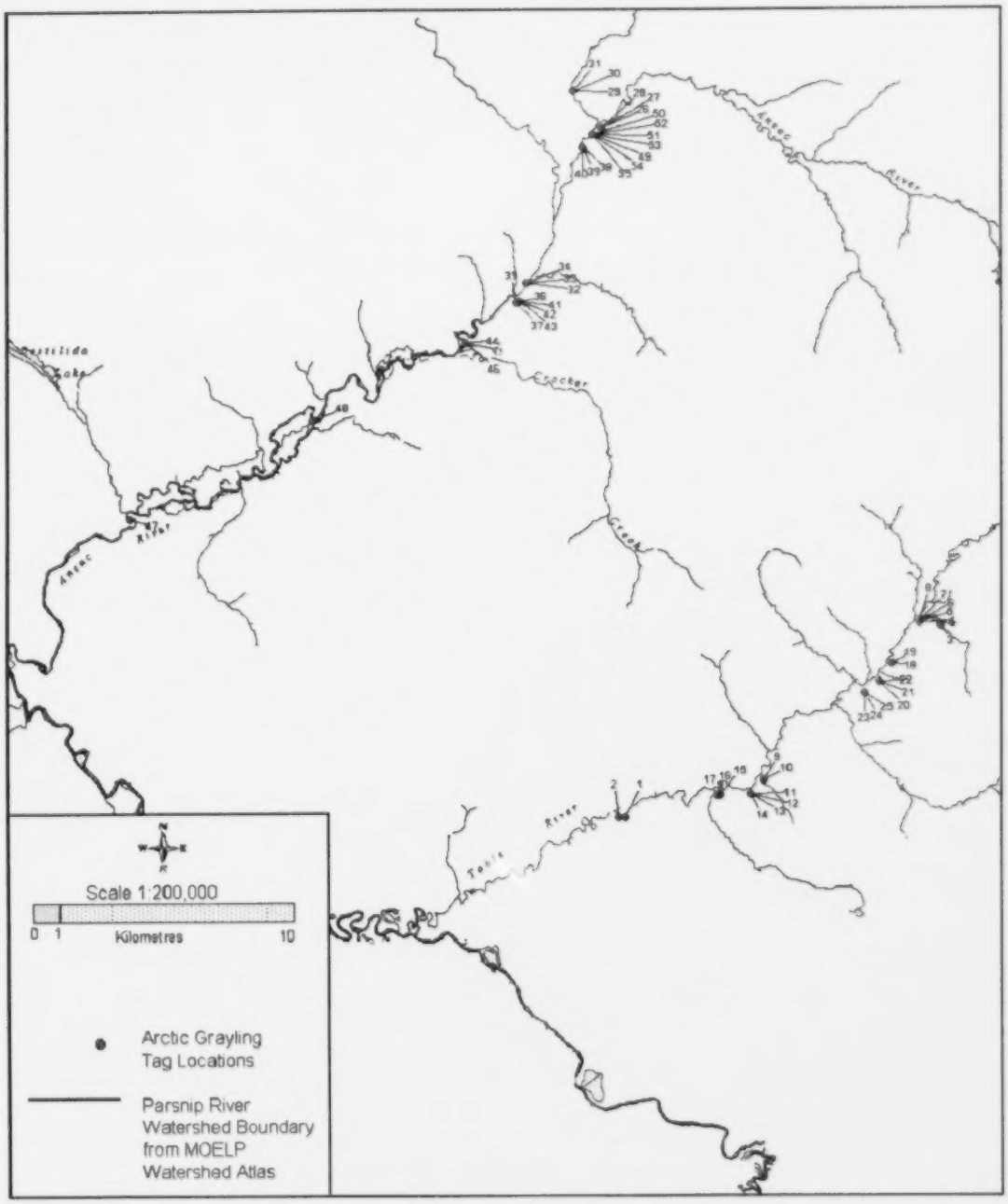
The average time required for the grayling to become anaesthetised was 178 seconds, average surgery time was 240 seconds and time for recovery (fish was able to hold itself upright) was 286 seconds (Blackman in prep). No fish died during surgery, all fish swam away from the recovery pen in an upstream direction and appeared to be in good condition. One fish (#49)was recaptured by angling, 30 minutes after being released.

Underwater observations were conducted to monitor the survival of the tagged fish during the September 19 and 24 telemetry flights. Underwater visibility was low (<1m) and so only a small number (6) of tagged fish were checked, primarily those located in areas with shallower water and better visibility. Only two tagged fish (27& 52) were observed and these appeared to be healthy. The divers were unable to observe the other four fish (7, 13, 17 and 37) and fish number 13 was suspected to be a mortality (transmitter sign was coming from a shallow riffle area).

Survival Rates of the Tagged Fish

Survival rates for the Table River grayling were very poor with only three fish (19, 23, 24) returning to the stream the following spring (Appendix A). Two transmitters (2,14) were located in an eagle nest and one (16) was located on the hillside adjacent to overwintering areas on the Parsnip River. It is not known if the fish were killed by the eagles, or if they had died and were eaten after. Two of the tags (7,25) disappeared after moving downstream 14 and 49 km in September. Three fish (1,3,15), were assumed to have died during the winter after showing upstream movements (the movements could have been errors in telemetry). (Fish #15 was recaptured in 1998 with no sign of a radio transmitter.) Six fish (9,10,12,17,18,22) died in overwintering areas on the Parsnip River and eight fish (4, 5, 6, 8, 11, 13, 20, 21,) were assumed to have died within a few kilometres of the release locations.

Survival rates for the Anzac River grayling were higher, with fifteen of the thirty fish returning to the river the following spring. One fish (33) was presumed eaten by predators. Five tags disappeared prior to the spawning period. Three (35, 45, 51) of these were last detected in Williston Reservoir during May or June. The other two (40,47) were last recorded in the lower Parsnip River. Four grayling (38, 42, 44, 53) appear to have died prior to spawning but after showing upstream movements during the winter. Three (30, 32, 50) died in the overwintering areas, one fish (55) died near its release location, and one fish (27) never showed an upstream movement but spent the winter in the Anzac River, then moved downstream to a main spawning area during the spawning period. After the spawning period it moved downstream again to an area where grayling have been observed to congregate, but when the other fish were moving upstream to summer feeding areas (Appendix A).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0 1 Kilometres 10
Arctic Grayling Tag Locations
Parsnip River Watershed Boundary from MOELP Watershed Atlas

Figure 2 Arctic grayling Radio Tag Release Locations.

Migrations to Overwintering Areas

The three, tagged Table River grayling that returned to the river in spring, moved to overwintering areas by September 19th soon after being implanted with the radio tags. These fish (19, 23, 24) overwintered in the Parsnip River, 9 to 22 km downstream from its confluence with the Table River (Fig 3). Only one (19) of these remained at the same location all winter. The average movement to overwintering areas (release to Feb 19 location) was 49 km with a maximum of 55 km and a minimum of 39 km (Appendix A, Table A2).

The fifteen tagged Anzac River grayling that moved upstream to spawn in the spring of 1997, had moved to overwintering areas by November 6th, 1996. (No flights were conducted between September 24 and November 6.). One fish (26) remained in the lower Anzac river all winter but the rest were located in the Parsnip River from 3 km upstream from its confluence with the Anzac River to 38 km downstream (Fig 3). Ten of the thirteen fish showed movements greater than one km during the winter (November 6 to April 16). Most were only one or two km moves but two fish (46, 52) moved 16 and 22 km. The average movement to overwinter areas (release to Feb 19) was 55 km with a minimum movement of 34 km and a maximum of 76 km (Appendix A, Table A2).

Migrations to Spawning Areas

The majority (13 of 18) of the grayling started moving towards spawning areas (Fig. 4), in late April or early May (Appendix A, Table A2), although some fish did not move until late May. The late April movement coincided with rising water temperatures, increased flows, and spring break up (Figs. 5 & 6). The average movement from overwintering areas to spawning areas (March 25 to June 13) was 33 km with a minimum movement of 9 km and a maximum of 71 km (Appendix A). Many males (26, 31, 34, 36, 39, 46, 52, 54) remained at one location throughout the suspected spawning period from May 29 to June 25. Some females (23, 24, 29, 37) moved upstream throughout the spawning period, while others (28 and 48) remained at the same location. One male, (41) showed slight upstream movements during this period. Fish that remained at one location during the spawning (May 29 to June 25) period arrived by May 22 or shortly after (Appendix A, Table A2).

Migrations to Summer Feeding Areas

Eight of the eighteen fish that were assumed to have spawned returned to the summer feeding locations where they had been tagged the previous year. These movements were primarily in July, although one fish (28) did not reach the area where it had been released until October. Three fish (34, 36, 54) disappeared after spawning, one fish (46) remained at the spawning area and one fish (43) moved downstream from the spawning areas. The remaining five fish (19, 24, 29, 31, 37) moved upstream after spawning but not as far upstream as the site where they were tagged (Appendix A, Table A2).

Overwinter Areas

There were no large concentrations of tagged fish at any one location during the winter, as had been expected. Rather, the fish were spread out along the Parsnip River (Fig. 3). There also was much more movement during the winter than had been anticipated (Appendix A Table A2). It was at times difficult to determine the exact locations of overwintering fish and some of the locations could be off by up to 100 m because of poor signal reception. Table River fish overwintered (December 16, February 19 and March 25 (1997) flights) in the

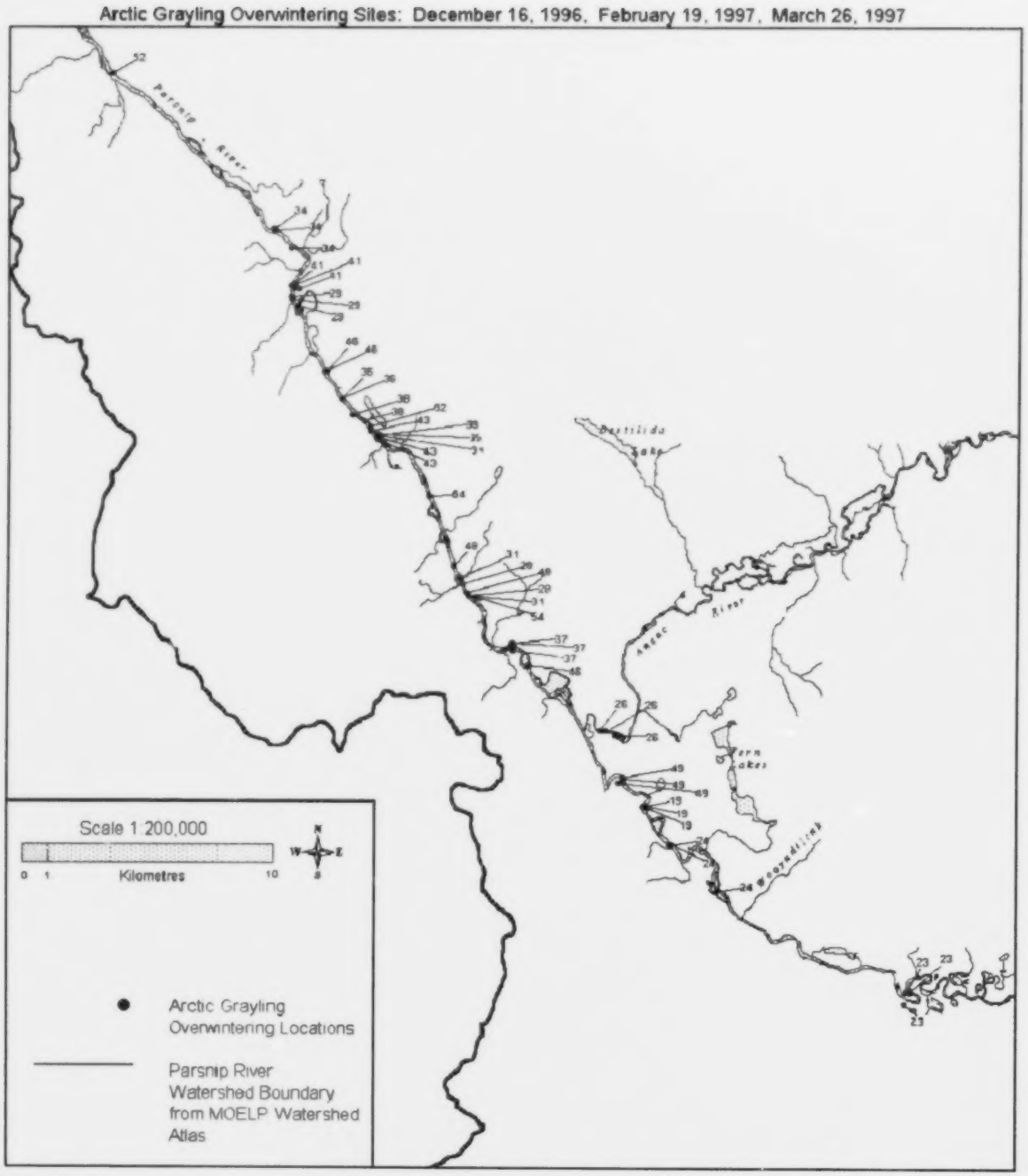

Figure 3. Radio tagged Arctic grayling overwinter locations (Dec. 16, Feb.19 and Mar 26,1997).

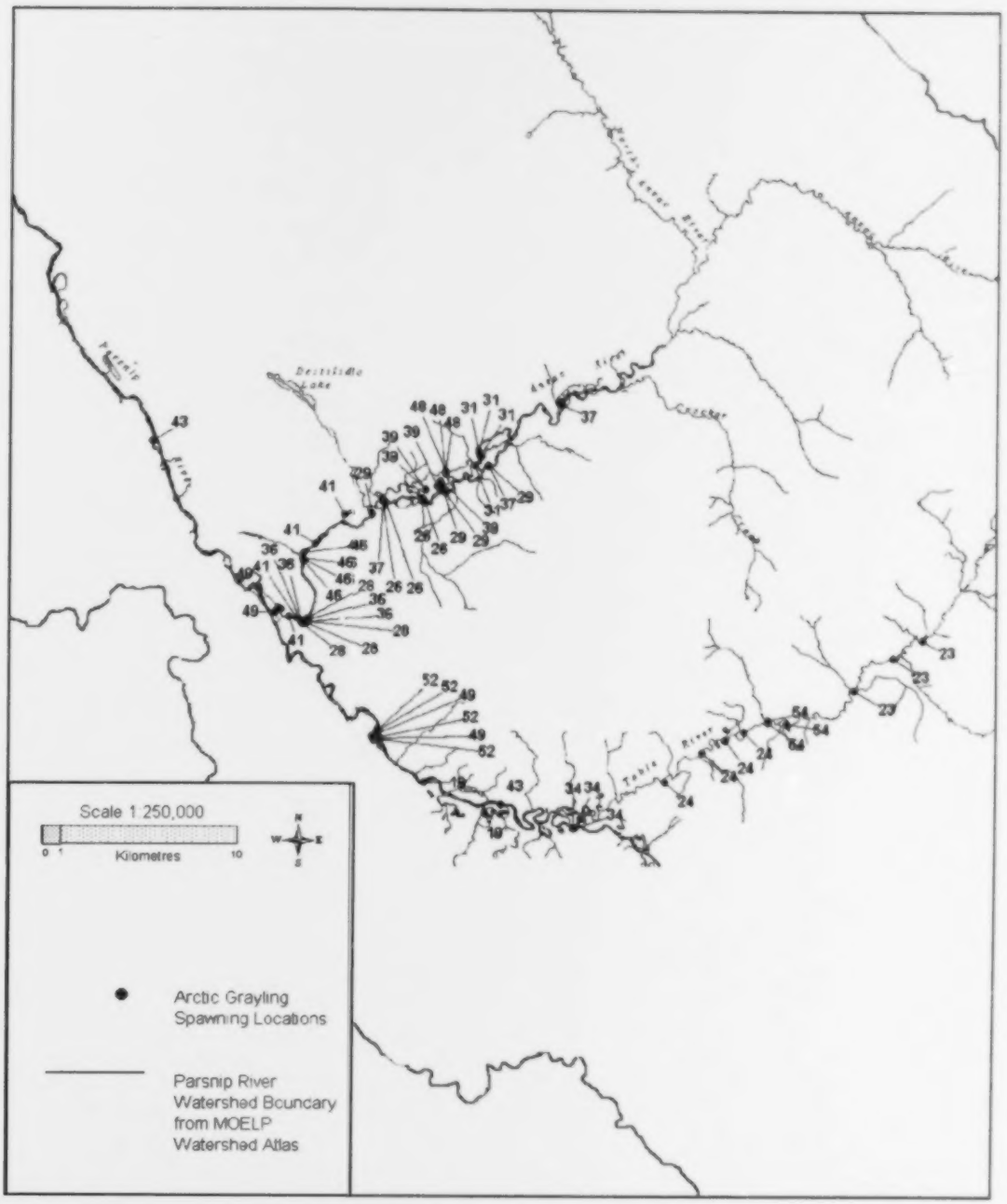

Figure 4 Suspected spawning locations of radio tagged Arctic grayling (May 29, June 6, 13, and 19, 1997).

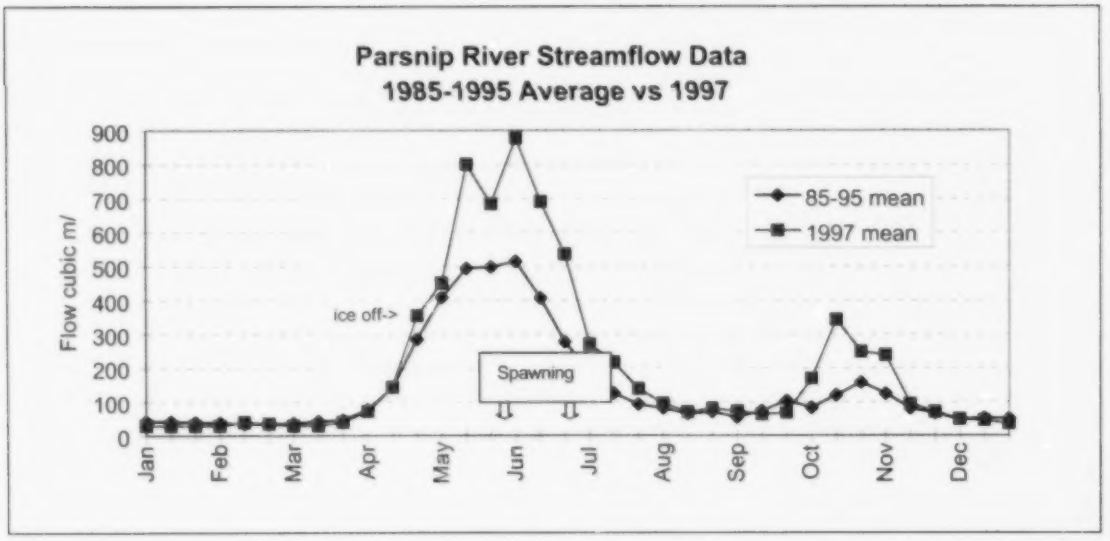

Figure 5 Average 10 day Discharge for the Parsnip River 1985-95 vs. 1997

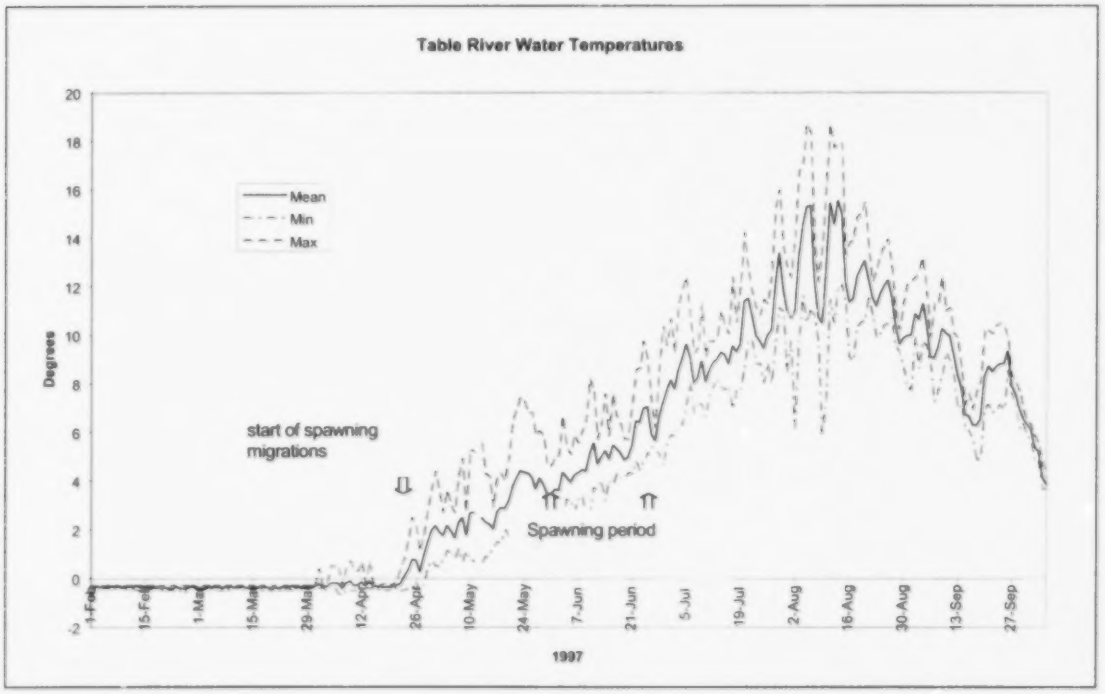

Figure 6. Table River Water Temperatures 1997

Parsnip River from 9 to 22 km downstream from the Table confluence. Most (13 of 15) Anzac River fish overwintered in the Parsnip from the Anzac confluence to 38 km downstream. One fish wintered in the lower Anzac and one overwintered in the Parsnip just upstream from the Anzac confluence. Only one fish remained in the tagging streams despite the presence of numerous deep pools and debris cover.

Habitat surveys were conducted from September 30 to October 2,1997, on 10 overwintering sites, (Appendix B) located between km 44 and km 69 of the Parsnip River. These sites were chosen because they represented the most precisely marked overwinter locations. Three of the sites (36, 37, 54) were long, almost featureless glides but the other seven sites were in, immediately below or immediately above riffles (19, 24, 26, 43, 46) or (39, 43) islands (Appendix B). The maximum cross sectional water depth where the fish was located, ranged from 1 to 2.8 m in depth with an average of 2.1m, and all fish were in areas with gravel or gravel cobble substrate (Appendix B). Water depths would have been much less during the winter and ice cover in many of the locations would have been up to one meter thick. The water flow rates from December to March, 1996, averaged 31 m^3/sec (Water Survey of Canada). When the depth measurements were recorded, heavy rainfall caused the river level to rise from 87 m^3/sec on September 30 to 222 m^3/sec on October 2,1997.

Spawning Area Characteristics

Spawning (based on water temperature, incubation and growth rate data) was believed to have occurred from May 29 to June 25, starting at the peak of spring freshet (Fig 5). During this period the grayling were located in deep pools, debris jams or in flooded riparian areas, close to but not in potential spawning habitat (shallow gravel riffles or glides). No exact spawning sites were located because the fish never appeared to be on a potential spawning site.

There were two main areas on the Anzac River (Fig. 4) where fish gathered during the spawning period. Four grayling (28, 36, 41, 49) were located about 3 km upstream from the river mouth. This area has several small islands and one very deep pool (>3m) created by a large debris jam. Seven tagged grayling (26, 29, 31, 37, 39, 41, 48) were found in the second area between km 12 and km 22. This area has multiple channels meandering through the valley flat, which is up to 2 km wide. During peak flows most of this low lying area was under water. Fish 46 moved out of the Parsnip River and up the Anzac River 6 km in April prior to the spawning period and did not move again.

There were insufficient numbers of tagged grayling in the Table River to identify key spawning locations. Fish 54, which was tagged at km 46 of the Anzac River, spent the spawning period between km 16 and km 18 of the Table River. Two female grayling (23 & 24) moved upstream in the Table River from km 21 to km 29 and from km 8 to km 17 respectively. Grayling 34 spent most of the spawning period (May 29 to June 13) near the mouth of the Table River. On June 19 it was not found and on June 25 it was at km 11 of the Anzac River. Grayling 19, which was tagged in the Table river, was located only twice (May 29 at km 77 and June 19 at km 80 of the Parsnip River) during the spawning period. The km 80 location was near the mouth of a small tributary stream, which subsequently was found to have grayling fry.

Five grayling (19,34,43,49,52) were in the Parsnip River (Fig 4) during the spawning period. Two Anzac fish (52, 49) were located in two different side channels of the Parsnip River at approximately km 74. Grayling 43, a female moved up and down the Parsnip River before entering the Anzac on June 26.

DISCUSSION

Survival rates of radio tagged fish

Prior to the initiation of this project there was concern about survival rates of the radio tagged grayling and if enough would survive to document spawning distribution. In order to provide the information required the radio tags would need to transmit for nearly one year. The smallest tag that met the requirements weighed 7.7g. Radio tags should not weigh more than 2% of the fishes body weight (Winter 1983, McKinley et al. 1992) so grayling would have to be greater than 385 g. Table River grayling do not reach this size until they are at least five years old (mean weight at age 5 is 357g, data on file). By age five they are approaching old age, with a corresponding higher natural mortality rate. The inexperience of the tagging crew probably contributed significantly to the high mortality rates, particularly in the Table River. Other possible problems would include post surgical infections, predation, particularly by bull trout, movement out of the study area, tag loss and failure of the tags.

Eight of the fish tagged in the Table River were assumed to have died shortly after tagging and within a few kilometres of the release site. This may have been due to the limited experience of the tagging crew. The surgical techniques (size and placement of the incision, anaesthetic application, suturing of the incision, sterile procedures and the time required for surgery) had improved by the time the crew moved to the Anzac River. Only 1 of 30 fish tagged in the Anzac River appeared to have died near the tagging sites.

The grayling from the Table River that were radio tagged had an average weight of 386 g, just at the 2 % rule (Winter 1983, McKinley et al 1992). The Anzac River fish were much larger averaging 449 g. Although the small size of the fish was a concern this may not have been the prime cause of the high mortalities. The average weight of the tagged grayling that survived was 366 grams for the Table and 440 grams for the Anzac, which is slightly lower than the average weight of the fish tagged. Although this is not significant ($p<0.05$ students T test), it suggests that larger (older fish) may have had lower survival rates.

A lower percentage of the older fish did survive to spawn (Fig. 7). Grayling from these rivers should have a natural mortality of at least 40% between age five and six and 70% between age six and seven (based on age class distributions in these two systems from samples collected from 1995 to 1997). This age class distribution is similar to that reported by other authors (Stuart and Chislett 1979, Tack 1971) and found in other systems within this watershed (Fig. 8). Barrett and Halsey (1985) estimated mortality rates for Arctic grayling from Williston Reservoir at 51% between age four and five and 71% between age five and six. Tack (1974) estimated mortality rates of 40% between ages three and four, 50% between ages four and five and 60 % between ages five and six for Alaskan stocks.

Seven tags disappeared prior to spawning. One fish (15) shed its radio tag. The tag was located at km 79 of the Parsnip River on September 19 and moved upstream 3 km by September 24, but no other movement was recorded and it was assumed that this fish had died. In 1998, this same fish, identified by its floy tag number, was recaptured in the Table River without any visible signs of a radio tag. Shedding of radio tags is unusual but does occur. Sterilisation of the tags before they are implanted could reduce this risk.

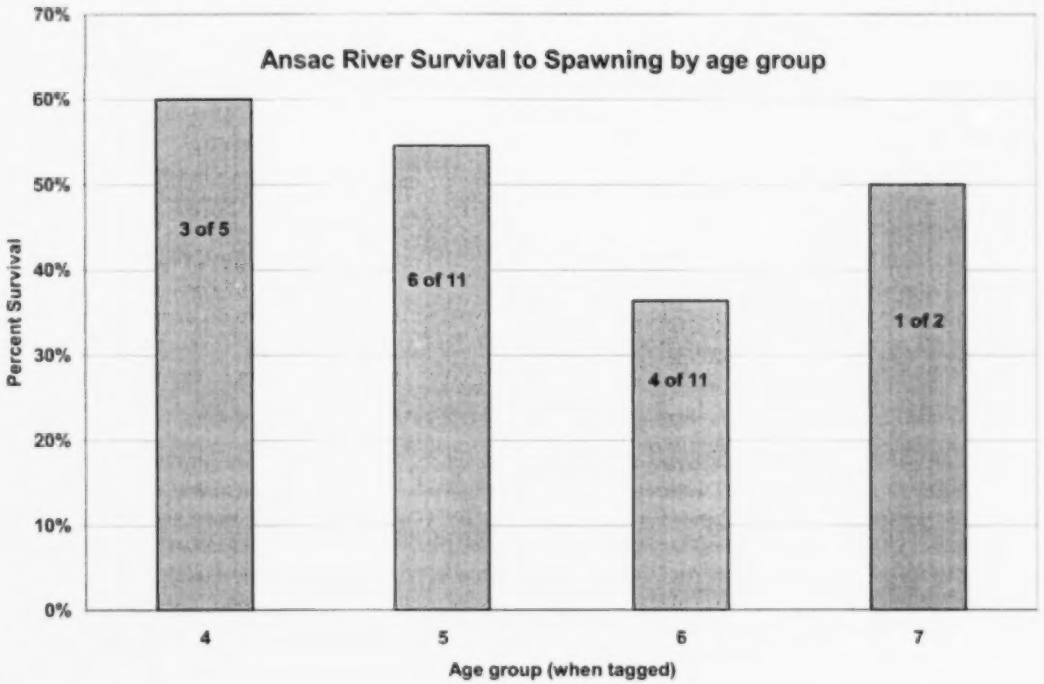

Figure 7. Percent of tagged Anzac River grayling from each age group that survived to the spawning period.

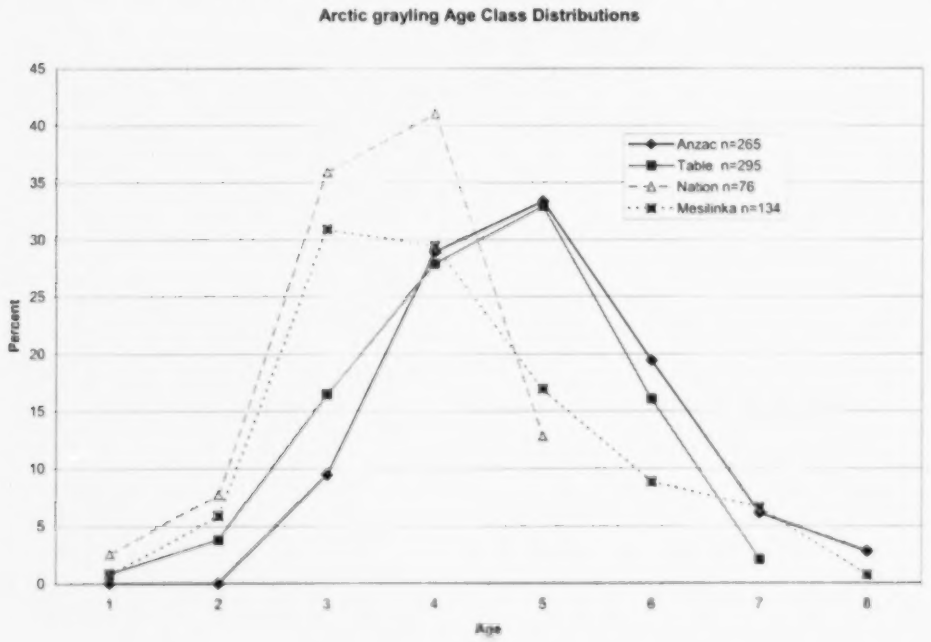

Figure 8 Age Class Distribution of Arctic Grayling captured by angling from 1990 to 1997 from the Anzac, Table, Nation and Mesilinka Rivers.

Substantially more radio tagged fish should be used to identify the spawning areas in future studies. In order to improve the survival rates, crews should have more experience in surgically implanting the tags. Smaller tags should be used particularly in the Table River so that younger individuals can be tagged. To reduce the chances of tags being "lost" a wider search area would have to be covered. Tack (1980), Armstrong (1986), and Ridder (1994) suggest that grayling have a strong affinity to return to the same stream, but they frequently utilise different streams for different life history stages (6 of 18 fish did not appear to spawn in the stream where they were tagged in this study). Radio telemetry may not be the most cost effective method to identify spawning areas in situations where adults captured and tagged at one location may spawn in different systems over a wide geographic area.

Migrations to Overwintering Areas

The tagged grayling moved out of the Table River to overwintering areas in the Parsnip River by late September. The implanted grayling from the Anzac did not move out until after September 24. The reason for this difference in timing is not known, but the Anzac River is larger and daily average water temperatures were on average 0.6° C warmer than the Table River during the month of September 1997 (data on file).

Migrations to Spawning Areas

Fish started to migrate to spawning areas at spring break up around April 30 when water temperatures rose above zero (Figs. 5 & 6), a pattern similar to that noted by Armstrong (1986). High river discharge and turbidity made it impossible to observe spawning activities, so the spawning period was calculated to be between May 29 and June 25 based on the fry emergence dates and water temperatures. However, our estimates may have been a week late, judging from observations of the arrival and departure from suspected spawning areas of tagged fish. These dates are in the later part of the range reported for other areas (Butcher et al. 1981). The initiation of the estimated spawning period does coincide with 4°C water temperatures (Fig 6) reported by most authors (Armstrong 1986; Butcher et al. 1981; Northcote 1993) to initiate spawning. We believe most male grayling (26, 31, 34, 36, 39, 46, 52, 54) arrived at the suspected spawning areas by May 22 (Appendix A Fig. A1) when the average daily water temperature reached 4°C and remained at the same location for nearly one month. Three males (34,49,52) had started moving upstream by June 25 suggesting that they had completed spawning by that time. The literature suggests (Rawson 1950, Reed 1964, Van Wyhe1964, Bishop 1967 and 1971, Tack 1971, Kratt and Smith 1977and 1979, and Kratt 1977) that males arrive first on the spawning grounds and that spawning may occur over a one month period, but that individual fish have a shorter duration (one week) on the spawning grounds. Both male and female grayling are highly polygamous. However these studies were not based on telemetry but on observations of individual fish.

During this same period some females (23, 24, 29, 37) exhibited a slow upstream movement, which ranged from one km per week to over two km per day. Tack (1971) reported that females remain in deep pools and entered the riffles only for short periods to spawn. This upstream movement has not been reported by other authors. It is not known if the females had completed spawning and were slowly moving to summer feeding areas or if they were moving upstream in search of different partners. However, newly hatched grayling fry were later observed at the maximum upstream locations that these females reached during the spawning period.

Migrations to Summer Feeding Areas

Movements to summer feeding areas were initiated soon after spawning. The tagged fish showed a distinct affinity to return to the areas where they had been tagged, a pattern similar to that reported by Tack (1980). Personal observations suggest that the distribution of adult grayling in the Anzac River was more concentrated in the upper river (canyon) in 1997 than in 1996, although none of the tagged fish were observed upstream of the locations where they had been tagged. A local guide confirmed that he had observed similar changes in summer feeding distribution depending on annual changes in water levels.

The maximum distance travelled from the initial tagging to return to summer feeding areas (~ one year) was 245 km, the average was 126 km and the minimum was 67 km. Males tended to travel slightly greater distances (135 km average) compared to females (110 km average). The extent of these movements is similar to patterns found by other authors (Armstrong 1985, Tack 1980).

Migratory Patterns

The migratory patterns displayed were highly variable. Our observations show a pattern where males remain at the spawning locations for one month and females slowly move upstream, which has not been reported elsewhere, and warrants further investigation. The pattern of overwintering, spawning and summering in different systems has been noted in other areas (Armstrong 1986). It is not known if these movement patterns are random, learned or genetic.

Overwintering Areas

Snorkel counts conducted in September in the Table and Anzac rivers frequently find large concentrations of fish (Arctic grayling, mountain whitefish, bull trout, and rainbow trout) in deep bedrock or debris jam controlled pools (pers. obs.), which were assumed to be overwintering habitat. It had been anticipated that the grayling would overwinter in this type of area, which is widely available in the Table (Mathias et al. 1998) and Anzac rivers (data on file). Only one tagged fish overwintered in the Anzac and none in the Table. The one fish (26) that overwintered in the Anzac River did not utilise deep pool habitat but was found in a relatively shallow glide / run habitat with moderate velocities and with no area over 2 m in depth. During the winter there would have been less than one meter of water at this location. The remaining grayling overwintered in the Parsnip River. Surprisingly, many of these grayling overwintered in shallow, higher velocity areas associated with riffles, side channels, islands or mid channel bars. These habitats appeared to be more like feeding locations rather that deep slow resting areas (Appendix BI).

Only four fish remained at one location during the period from November to March but nine fish remained at the same locations from December to March suggesting fish may move around looking for suitable overwinter areas. Three fish (33, 35, 51) were found in the reservoir during the winter and previous studies (Anonymous 1978, Bruce and Starr 1975) have suggested that the reservoir may be an important overwintering area for a number of species. However, none of the fish that moved to the reservoir returned to spawn.

Some of these fish may have become "lost" or strayed into other systems. In the mid 1970's a rainbow trout floy tagging study was conducted at W.A.C. Bennett Dam during the winter (data on file). The tag return data from this study showed that many fish travelled great distances (up to 200 km) in the reservoir. Subsequent tagging studies suggest there is still a high degree of straying by rainbow trout in the reservoir (data on file). Large numbers of Arctic grayling were also captured but not tagged during the initial study, demonstrating that grayling utilised the reservoir for overwintering. It is possible that grayling overwintering in the reservoir would have greater propensity to stray or not return to their natal stream.

Much more detailed information is required to clearly identify the habitat parameters required by Arctic grayling for overwintering. Given the wide variety of areas utilised and the mobility of these fish during the winter, lack of overwintering habitat may not be a critical factor.

Spawning Areas

Insufficient numbers of tagged grayling survived to spawn to ensure identification of key spawning areas in the Table and Anzac rivers. Two highly utilised areas were identified in the Anzac River but subsequent ground surveys (data on file) found newly hatched grayling fry several kilometres upstream from these areas . One tagged female (37), which moved upstream continuously during the spawning period was located near the uppermost distribution of fry.

The suspected spawning areas of the Anzac River (based on telemetry and fry distribution data) all had extensive shallow glide areas with large quantities of small (<3 cm) gravel and were located in areas of the river that were multi-channelled. The upper limits of spawning coincided with a decrease in the percentage of gravel and an increase in cobble and boulder percentage (Mathias et all 1998, and data on file).

Arctic grayling frequently spawn in shallow water, 10-30 cm in depth (Kratt 1977, Sempeski and Gaudin 1995). Water levels in the Table and Anzac rivers may drop up to one meter (pers. obs.) between the time the grayling spawn and when the fry hatch. Utilisation of multi channelled areas may be an adaptation to compensate for fluctuating water levels and to provide increased protection for newly hatched fry from increased water velocities during higher flow periods. Multi channelled sections of the river should have less extreme fluctuations in water levels and provide more low velocity areas than single channel habitat. Stuart and Chislett (1979) reported use of mainstem sidechannel areas as spawning sites in the Sukunka River and Stanislawski and Brown (1997) suspected sidechannel spawning in the Little Smoky River drainage.

Tagged grayling that reached the suspected spawning areas arrived by May 22, and most spawning was estimated to have been completed by June 25. This is somewhat later than the norm reported by many authors (Armstrong 1986, Butcher 1981, Stewart et al, 1982, Northcote 1993) but not beyond reported ranges (Armstrong 1986). A possible explanation would be in 1997 spring runoff was later or more extended. Spring runoff normally peaks in late May and early June in this area (Fig 6). The higher than normal flows may also have affected the distribution of spawners.

Five of the fifteen surviving Anzac grayling and one of the three Table fish spent the spawning period in rivers other than the streams they were tagged in. This pattern, summering in one system and spawning and overwintering in different systems is fairly common (Armstrong 1986, Stein et al 1973). One Anzac grayling (54) spent the spawning period in the Table River, and one Table River grayling (19) appears to have spawned in a small tributary stream flowing into the Parsnip River. Two Anzac grayling (49, 52) were in side channels of the Parsnip River. Two other Anzac fish (34, 43) were in the Parsnip River but the locations they were found in did not appear to be suitable spawning areas. Subsequent ground surveys (data on file) found young of the year grayling fry at all the suspected spawning locations except those in the Parsnip River mainstem, although conditions were less that ideal at the time of the surveys and high flows may have affected survival rates. Previous studies (Anonymous 1978) found both fry and juvenile Arctic grayling utilising the mainstem of the Parsnip River.

No exact spawning locations were identified, possibly because the surveys were conducted to early in the day. The suspected spawning areas were surveyed first (starting at 0930 A.M.) to ensure these areas were thoroughly covered, as it was most difficult to cover the entire area in one day. This may have been a possible reason why the grayling were located in deep pools rather

than in potential spawning areas during the surveys. Most spawning occurs in mid to late afternoon (Beauchamp 1990, Van Wyhe1964). Female grayling hold in deep pools and only enter the spawning grounds for short periods (Tack 1971, Beauchamp 1990). The males remain on the spawning grounds defending their territories throughout the spawning period (Beauchamp 1990, Kratt and Smith 1980.) or may retreat to deep pools during the evening and return to the spawning grounds the next day (Bishop 1971). It appears that our grayling may have retreated to the deeper pools and had not moved back to the spawning areas by the time the surveys were conducted. It would be advisable, in the future to have the tags programmed to transmit for ten to twelve hours per day during the spawning period to allow surveys to be conducted later in the day and to cover a greater area.

These surveys did not identify all of the spawning areas, because insufficient numbers of radio tagged grayling survived to spawn. The identification of spawning habitat characteristics was hampered by higher than normal flows and problems with the survey design (Appendix III). Radio telemetry will provide information on spawning distribution over a large area but it is a costly technique. The cost of this project was over $200,000, but this could be reduced considerably on future surveys.

Management Implications

The identification and protection of spawning and early rearing areas is of prime importance in efforts to prevent further declines in Arctic grayling populations. The vulnerability of newly hatched grayling fry to floods is cited throughout the literature with numerous year class failures attributed to high stream flows (Armstrong 1986, Nelson 1954, Tack 1974, Stewart and Chislett 1979.). Reynolds (1989) in his evaluations of the Arctic grayling habitat suitability index model (Hubert et al. 1985) states that for optimum conditions at least 30% of the area adjacent to spawning sites must be low velocity (<15cm/sec) backwater habitat. These backwaters provide the most favourable rearing habitat and refuge from high water velocities during high water events. The availability of backwater habitat is seen as a key factor to grayling production.

The Arctic grayling tracked in this study concentrated in multi-channelled areas of the Anzac River during the spawning period. This type of habitat would potentially provide better protection for newly emerged fry from high flows than less complex single channelled areas. The concentration of spawners at certain locations emphasises the importance of locating and protecting these habitats from any detrimental impacts. The telemetry also identified that grayling spawned in systems other than where they spent the summer (#s19, 34 ,43, 49, 52, & 54) which clearly indicates that monitoring of populations particularly in response to management or enhancement activities cannot be limited to a small geographic area and it may be necessary to determine what life history stages are utilising different areas in order to develop effective monitoring programs.

Radio telemetry, although expensive, is an effective method to locate critical areas. However, there are difficulties with identifying exact spawning locations because of spring runoff conditions. Another problem is that low numbers of tagged fish may survive to spawn, and the potential wide geographic distribution of the tagged fish may not be sufficient to identify all spawning areas. The use of fry distribution studies is currently being examined as a more cost effective method to locate spawning areas, (Blackman and Hunter, 2001) but this type of study would not provide information on migratory patterns and utilisation of different systems. Fry distribution studies are also be limited in that they only document areas where fry survived in that particular year, and work on the assumption that the fry remain near the spawning areas and do not distribute downstream.

SUMMARY

1. Fifty five Arctic grayling from the Table and Anzac Rivers were surgically implanted with radio transmitters. Only 18 of these fish are confirmed to have survived to spawn the following year.

2. Movements to overwintering areas occurred prior to September 24th for the Table River grayling and prior to early November for the Anzac River grayling. Movements to overwintering areas averaged 55 km downstream with a range of 34 to 80 km.

3. The selection of overwintering habitats was highly variable, deep pools in the summer feeding streams were not selected and there was movement throughout the winter.

4. The initiation of migrations to spawning areas coincided with rising water temperatures and spring break up. The average movement from overwinter to spawning area was 33 km with a range of 9 to 71 km.

5. Spawning was believed to occur during spring flood conditions. The timing of spawning was estimated by using water temperature and degree days to hatch data.

6. Generally, males arrived at the spawning areas before the females. Six of the nine surviving males remained at one location for up to one month during the spawning period, which occurred from late May to mid June.

7. A number (4 of 7) of female Arctic grayling exhibited a slow upstream movement during the spawning period.

8. Nearly one third (5 of 18) of the fish appeared to have spawned in systems other that where they spent the previous summer.

9. There were two multi-channels sections of the Anzac River where spawners congregated and most of the suspected spawning areas contained large patches of small (<3 cm) gravel.

10. A high percentage (9 of 14)of the fish returned to summer in the same area where they were tagged the previous year.

11. The average movement for the 13 month period was 126 km with a maximum movement of 245 km and a minimum of 67 km.

12. There were insufficient numbers of radio tagged Arctic grayling spawning to identify all areas of spawning activity within these drainages.

13. The poor survival rates were probably a combination of the small size of the fish that were tagged, high natural mortality rates as a result of tagging older individuals in a short lived population, the inexperience of the tagging crew, along with normal telemetry problems such as fish moving out of the study area, tag failure, predation and shedding tags.

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Appendix A
Arctic Grayling Locations and Movements

Table A1 Arctic Grayling Tagging Locations and Survivals

Radio Tag #	Fork Length(mm)	Weight (g)	Age	Tagging Date	Sex	Tagging River	Location km	Comments
1	320	264	5	96/08/22		Tbl	15.5	mort after U.St movmts in winter
2	315	260.8	4	96/08/22		Tbl	14.6	mort eagles nest 35 km from release site
3	342	482	6	96/08/23	F	Tbl	35.3	mort after U St. movmts in winter
4	333	408	5	96/08/23	M	Tbl	34.3	mort 12 km D St. from release site
5	330	418	5	96/08/23		Tbl	34.3	mort 12 km D St. from release site
6	322	379.6	5	96/08/23		Tbl	34.3	mort 4 km D St. from release site
7	350	532	7	96/08/23	M	Tbl	34.3	disappeared last seen Sept 24
8	325	341	5	96/08/23		Tbl	34.3	mort 5 km D St. from release site
9	332	403	5	96/08/27	M	Tbl	22.7	mort 48 km D St.
10	345	432	6	96/08/27	M	Tbl	22.7	mort 44 km D St.
11	332.5	359	4	96/08/27	F	Tbl	22	mort 15 km D St.
12	300	311	5	96/08/27	F	Tbl	22	mort 34 km D St.
13	330	374	6	96/08/27	F	Tbl	22	mort 5 km D St. from release site
14	315	340.4	4	96/08/27	F	Tbl	22	mort eagles nest 35 km from release site
15	325	378	5	96/08/27	M	Tbl	20.2	mort 35 km D St. after U St. movmt
16	340	330.9	4	96/08/27	F	Tbl	20	mort 38 km D St. on hillside 1 km from river
17	324	374	4	96/08/27	M	Tbl	20	mort 20 km D St.
18	349	492	5	96/08/28	M	Tbl	31.9	mort 92 km D St.
19	317	341	4	96/08/28	M	Tbl	31.9	spawned in a trib of Par, returned to Tbl R
20	328	369.2	5	96/08/28	F	Tbl	31	mort 25 km D St.
21	354	504	5	96/08/28	M	Tbl	31	mort 1 km D St.
22	334	392.9	5	96/08/28	M	Tbl	31	mort 71 km D St.
23	340	419	5	96/08/28	F	Tbl	30.2	spawned in Tbl River
24	320	340	5	96/08/28	F	Tbl	30.2	spawned in Tbl River
25	332	422.3	5	96/08/28	F	Tbl	30.2	disappeared, last seen Sept 19 49 km D St.
26	378	504	6	96/08/29	M	Anzac	47	spawned Anzac River .. returned release site
27	372	590	6	96/08/29	M	Anzac	47	unknown? no U St. movmt but D St. movmt
28	320	372.6	6	96/08/29	F	Anzac	47	spawned lower Anzac and returned torelease site
29	315	376	4	96/08/29	F	Anzac	52	spawned in the Anzac River
30	340	490	5	96/08/29	F	Anzac	52	mort 44 km D St.
31	344	473.3	5	96/08/29	M	Anzac	52	spawned Anzac River
32	345	419.7	5	96/08/30	M	Anzac	38	mort D St. 57 km
33	355	484.9	5	96/08/30	M	Anzac	38	mort but moved 100 km D St. to Res in Sept
34	362	561	6	96/08/30	M	Anzac	38	spawned in Par or lower Tbl and returned to Anzac
35	380	532	6	96/09/04	M	Anzac	38	disappeared last seen June 13 mouth of Riv in Res
36	370	504	5	96/09/04	M	Anzac	38	spawned lower Anzac R then disappeared
37	328	312.6	5	96/09/04	F	Anzac	38	spawned in the Anzac River
38	320	346	4	96/09/05	M	Anzac	45	mort after showing U St. winter movmt
39	328	377.6	5	96/09/05	M	Anzac	45	spawned Anzac River returned to tagging site
40	331	384.7	5	96/09/05	M	Anzac	45	disappeared last seen Mar 25 at km 48 of the Par R
41	378	610	7	96/09/05	M	Anzac	38	spawned Anzac R. returned to release site
42	355	561	7	96/09/05	F	Anzac	38	mort after U St. winter movmt
43	312	366	4	96/09/05	F	Anzac	38	spawned Par moved up Anzac and down Par
44	341	421	6	96/09/05	M	Anzac	33	assumed mort no U St. movmt
45	360	504	6	96/09/05	F	Anzac	33	disappeared last seenRes Apr 30 winter U St. movmt
46	349	452.5	4	96/09/05	M	Anzac	33	spawned Anzac... may have died near spawning area
47	313	328.5	4	96/09/06	M	Anzac	12	disappeared last seen Par R km 45 Sept 24
48	325	368.2	5	96/09/06	M	Anzac	24	spawned Anzac returned to release site
49	349	466.7	6	96/09/06	M	Anzac	46	spawned Par returned to release site
50	336	447.6	6	96/09/06	M	Anzac	46	mort 86 km D St. from release site
51	347	447	6	96/09/06	M	Anzac	46	disappeared 5 mo.Res...disappeared again
52	338	424.2	5	96/09/06	M	Anzac	46	spawned Par..returned to release site
53	341	414.7	5	96/09/06	F	Anzac	46	mort..after U St. movmt in fall
54	333	428		96/09/06	M	Anzac	46	spawned..Tbl R then disappeared
55	355	504	6	96/09/06	M	Anzac	46	mort

D St= downstream Par = Parsnip R. mort = mortality movmt= movement
U St = upstream Tbl = Table River Res = Williston Reservoir

Table A2

Radio Tag Location and Movements

					Tag Release Location		19-Sep			24-Sep				06-Nov			16-Dec			19-Feb			25-Mar		
Code	F.L.	Wt.	Age	Sex	R	km	R	km	M	R	km	M1	MT	R	km	M2	R	km	M3	R	km	M	R	km	M
1	320	264	5		T	15	T	6	-9	T	5	-1	-10	T	5	0	T	7	2	T	5	-2	T	5	0
2	315	261	4		T	15	P	71	-35				-35				P	71		trib P	eagle	snest	eagle	snest	
3	342	482	6	F	T	35				T	25		-10	T	26	1	T	25	-1	T	25	0	T	25	0
4	333	408	5	M	T	34	T	12	-22	T	12	0	-22	T	12	0	T	12	0	T	12	0	T	12	0
5	330	418	5		T	34				T	22		-4	T	22	0	T	22	0	T	22	0	T	22	0
6	322	380	5		T	34				T	30		-4	T	30	0	T	30	0	T	30	0	T	30	0
7	350	532	7	M	T	34	T	20	-14	T	20	0	-14												
8	325	341	5		T	34				T	30		-4	T	29	-1	T	29	0	T	29	0	T	29	0
9	332	403	5	M	T	23	P	66	-48	P	66	0	-48	P	66	0	P	66	0	P	66	0	P	66	0
10	345	432	6	M	T	23	P	70	-44	P	70	0	-44	P	70	0	P	70	0	P	70	0	P	70	0
11	333	359	4	F	T	22	T	7	-15				-15	T	7		T	7	0	T	7	0	T	7	0
12	300	311	5	F	T	22	P	79	-34	P	78	-1	-35	P	78	0	P	78	0	P	78	0	P	78	0
13	330	374	6	F	T	22	T	17	-5	T	17	0	-4	T	17	0	T	17	0	T	17	0	T	17	0
14	315	340	4	F	T	22																	P	71	
15	325	378	5	M	T	20	P	79	-32	P	76	-3	-35	P	78	2	P	78	0	P	78	0	P	78	0
16	340	331	4	F	T	20	P	73	-38				-39	P	73		P	73	0	P	74	1	hillside	near P 74	
17	324	374	4	M	T	20	T	20	0	T	20	0		T	6	-14	P	90	-7	P	90	0	P	90	0
18	349	492	5	M	T	32				P	31		-92	P	31	0	P	31	0	P	31	0	P	31	0
19	317	341	4	M	T	32	P	68	-55	P	68	0	-55	P	68	0	P	68	0	P	68	0	P	68	0
20	328	369	5	F	T	31	T	6	-25				-25	T	6		T	6	0	T	6	0	T	6	0
21	354	504	5	M	T	31				T	30		-1	T	30	0	T	30	0	T	30	0	T	30	0
22	334	393	5	M	T	31				P	51		-71	P	51	0	P	51	0	P	51	0	P	51	0
23	340	419	5	F	T	30	P	77	-44	P	76	-1	-45	P	72	-4	P	82	10	P	82	0	P	82	0
24	320	340	5	F	T	30	P	77	-44	P	76	-1	-45				P	74		P	69	-5	P	69	0
25	332	422	5	F	T	30	P	72	-49				-49												
26	378	504	6	M	A	47				A	7		-40				A	2		A	1	-1	A	1	0
27	372	590	6	M	A	47				A	46		-1				A	34							
28	320	373	6	F	A	47				A	31		-16	P	56	-38	P	55	-1	P	55	0	P	55	0
29	315	376	4	F	A	52				A	38		-14	P	37	-1	P	39	2	P	39	0	P	39	0
30	340	490	5	F	A	52				A	31		-14	P	63	-31	P	63	0	P	63	0	P	63	0
31	344	473	5	M	A	52				A	31		-14	P	55	-39	P	55	0				P	54	
32	345	420	5	M	A	38				P	44		-57	P	44	0	P	44	0	P	44	0	P	44	0
33	355	485	5	M	A	38				Res	0		-101	Res	0	0	Res	0	0	Res	0	0	Res	0	0
34	362	561	6	M	A	38				A	7		-31	P	36	-34	P	37	1	P	37	0	P	37	0
35	380	532	6	M	A	38	A	38	0	A	0	-38	-38	P	34	-29	Res	0	-34						
36	370	504	5	M	A	38	A	38	0	A	31	-7	-7							P	44		P	44	0
37	328	313	5	F	A	38	A	38	0	A	25	-13	-13	P	56	-32	P	60	4	P	60	0	P	60	0
38	320	346	4	M	A	45				A	38		-7	P	49	-52	P	44	-5				P	45	
39	328	378	5	M	A	45				A	17		-26	P	48	-32	P	48	0	P	48	0	P	48	0
40	331	385	5	M	A	45				P	60		-47	P	48	-12	P	48	0	P	48	0			
41	378	610	7	M	A	38	A	38	0	A	38	0	0	P	39	-62	P	39	0	P	39	0	P	39	0
42	355	561	7	F	A	38				P	39		-62	P	37	-2	P	39	2				P	38	0
43	312	366	4	F	A	38	A	38	0	P	63	-38	-38	P	45	-18	P	47	2	P	47	0	P	47	0
44	341	421	6	M	A	33											A	0		P	68	-5	P	60	-8
45	360	504	6	F	A	33	A	32	-1	A	32	0	-1	P	37	-58	P	48	11	P	25	-23	P	25	0
46	349	453	4	M	A	33	A	34	1	A	32	-2	-1				P	44		P	44	0	P	60	16
47	313	329	4	M	A	12				P	45		-29												
48	325	368	5	M	A	24	A	24	0	A	24	0	0				P	53					P	56	
49	349	467	6	M	A	46				A	46		0	P	66	-43	P	66	0	P	66	0	P	66	0
50	336	448	6	M	A	46	A	45	-1	A	31	-14	-15	P	22	-72	P	22	0	P	22	0	P	22	0
51	347	447	6	M	A	46	A	46	0	A	38	-8	-8												
52	338	424	5	M	A	46				A	46		0	P	49	-60	P	47	-2				P	25	
53	341	415	5	F	A	46	A	47	1	A	45	-2	-2	P	60	-48	P	60	0	P	60	0	P	60	0
54	333	428		M	A	46				P	63		-46	P	55	-8				P	55		P	50	-5
55	355	504	6	M	A	46											A	41		A	42	1	A	42	0

Code = Radio Tag #, R = River A-Anzac T- Table P- Parsnip Res- Reservoir km is the km on the river M =Distance traveled in km
M1 distance from Sept 19 to Sept 24 and MT total distance traveled to September 24
d/s downstream u/s up stream w/ mort died after upstream movement

Table A2 cont

Radio Tag Locations and Movements

	16-Apr			30-Apr			12-May			22-May			29-May			06-Jun			13-Jun			19-Jun			25-Jun		
Code	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M
1	T	5	0	T	5	0	T	5	0	T	5	0	T	5	0	T	5	0	T	5	0	T	5	0	T	5	0
2			eaglesnest			eaglesnest			eaglesnest				eaglesnest			eaglesnest			eaglesnest			eaglesnest			eaglesnest		
3	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0
4	T	12	0	T	12	0	T	12	0	T	12	0	T	12	0	T	12	0	T	12	0	T	12	0	T	12	0
5	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0
6	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0
7																											
8	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0
9	P	66	0	P	66	0	P	66	0	P	66	0	P	66	0	P	66	0	P	66	0	P	66	0	P	66	0
10	P	70	0	P	70	0	P	70	0	P	70	0	P	70	0	P	70	0	P	70	0	P	70	0	P	70	0
11	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0
12	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0
13	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0
14	nest		Tacheeda Ck			eaglesnest			eaglesnest			eaglesnest			eaglesnest			eaglesnest			eaglesnest			eaglesnest		
15	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0
16			0	near P 74					hillside near P 7			0			hillside near P 74						hillside near P 7		0			
17	P	90	0	P	90	0	P	90	0	P	90	0	P	90	0	P	90	0	P	90	0	P	90	0	P	90	0
18	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0
19	P	68	0	P	68	0	P	68	0	P	68	0	P	77	9							P ??	80				
20	T	6	0	Y	6	0	T	6	0	T	6	0	T	6	0	T	6	0	T	6	0	T	6	0			
21	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0
22	P	51	0	P	51	0	P	51	0	P	51	0	P	51	0	P	51	0	P	51	0				P	51	
23	P	82	0	T	4	13	T	6	2	T	15	9	T	22	7	T	26	4				T	29	29	T	29	0
24	P	69	0	P	73	4	P	73	0	P	85	12	T	8	14	T	11	3	T	13	2	T	14	1	T	17	3
25																											
26	A	1	0	A	1	0				A	1		A	12	11	A	12	0	A	15	3	A	15	0	A	15	0
27	A	34	0	A	22	-12	A	19	-3	A	17	-2	A	17	0	A	17	0	A	17	0	A	17	0	A	17	0
28	P	55	0	P	61	6				A	3		A	3	0	A	3	0	A	3	0	A	3	0	A	3	0
29	P	41	2	P	39	-2				A	8		A	12	4	A	22	10	A	21	-1	A	21	0	A	21	0
30	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0
31							A	10		A	16	6	A	18	2	A	22	4	A	22	0	A	22	0	A	24	2
32	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0
33	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0
34	P	37	0	P	38	1	P	50	12				P	90		P	90	0	P	90	0				A	12	
35	Res	0	0	Res	0	0	Res	0	0				Res	0	0	Res	0	0	Res	0	0						
36	P	44	0	P	56	12				A	3	3	A	3	0	A	3	0	A	3	0	A	3	0	A	3	0
37	P	60	0	P	56	-4	P	61	5							A	13		A	20	7	A	29	9	A	30	1
38	P	45	0	P	22	-23	P	39	17				P	39		P	39	0	P	39	0	P	39	0	P	39	0
39				P	61					A	13		A	14	1	A	17	3	A	17	0	A	17	0	A	17	0
40																											0
41	P	41	2	P	54	13	P	60	6	A	1	5	A	1	0	A	3	2	A	6	3	A	8	2	A	35	27
42	P	38	0	P	33	-5	P	33	0	P	33	0	P	33	0	P	33	0	P	33	0	P	33	0	P	33	0
43	P	47	0	P	47	0	P	47	0	P	47	0				P	82					P	52		A	3	14
44	P	56	-4													P	39		P	39	0	P	39	0	P	39	0
45	P	24	-1	Res	0	-24	Res	0	0																		
46				A	7					A	7		A	7	0	A	7	0	A	7	0	A	7	0	A	7	0
47																											
48	P	56	0	P	60	4				A	13					A	13		A	13	0	A	13	0			
49	P	66	0	P	66	0	P	66	0	P	74	8	P	74	0	P	74	0	P	63	-11	P	63	0	P	67	4
50	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0
51				Res	0		Res	0	0	Res	0	0	Res	0	0	Res	0	0									
52	P	25	0	P	27	2	P	27	0	P	74	47	P	74	0	P	74	0	P	74	0	P	74	0	P	43	-31
53	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0
54	P	54	4	P	66	12	P	71	5	T	11	31	T	16	5	T	16	0				T	18		T	18	
55	A	42	0	A	39	-3	A	39	0	A	39	0	A	39	0	A	39	0	A	39	0	A	39	0	A	39	0

Code = Radio Tag #, R = River A-Anzac T- Table P- Parsnip Res- Reservoir km is the km on the river M =Distance traveled in km
M1 distance from Sept 19 to Sept 24 and MT total distance traveled to September 24
d/s downstream u/s up stream w/ mort died after upstream movement

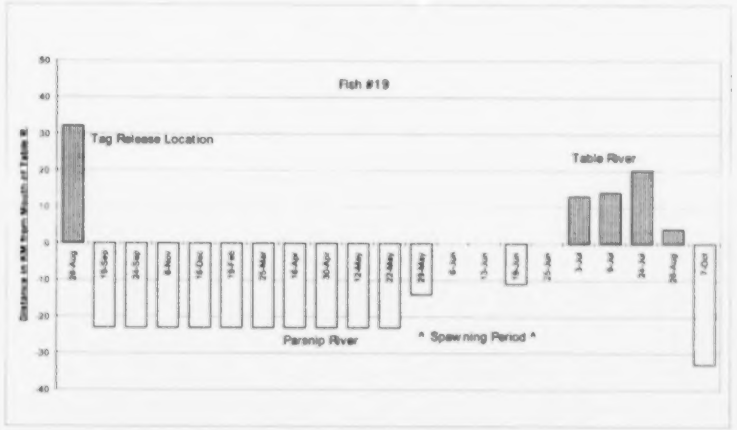
Table A2 cont

Radio Tag Locations and Movements

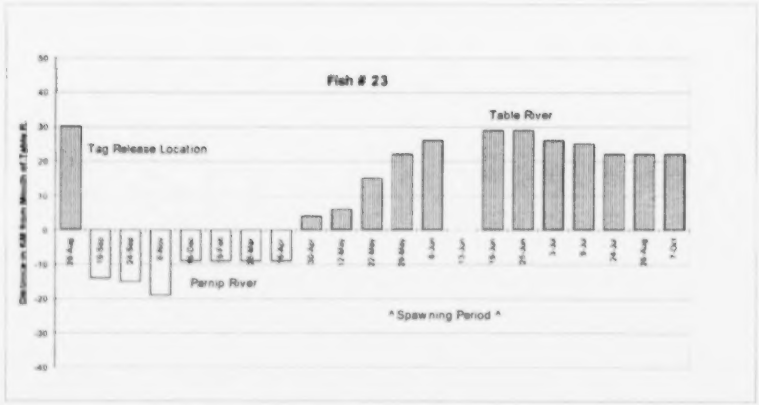
	03-Jul			09-Jul			24-Jul			26-Aug			07-Oct			
Code	R	km	M	R	km	M	R	km	M	R	km	M	R	km	M	M
1	T	5	0	T	5	0	T	5	0	T	5	0				d/s 19 km Table 1-2km us movement dec. w / mort
2	eaglesnest															d/s 35 km Sept eaglesnest mort /killed
3	T	25	0	T	25	0	T	25	0	T	25	0	T	25	0	d/s 10 km Table u/s 1 km Nov . mort
4	T	12	0	T	12	0	T	12	0	T	12	0				d/s 12 km Table mort
5	T	22	0	T	22	0	T	22	0	T	22	0	T	22	0	d/s 12 km Table mort
6	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	d/s 4 km Table mort
7																d/s 14 km Table disappeared
8	T	29	0	T	29	0	T	29	0	T	29	0	T	29	0	d/s 5 km Table mort
9	P	66	0	P	66	0	P	66	0	P	66	0				d/s 48 km Parsnip mort
10	P	70	0	P	70	0	P	70	0	P	70	0				d/s 44 km Parsnip mort
11	T	7	0	T	7	0	T	7	0	T	7	0	T	7	0	d/s 15 km Table mort
12	P	78	0	P	78	0										d/s 34 km Parsnip mort
13	T	17	0	T	17	0	T	17	0	T	17	0	T	17	0	d/s 5 km Table mort
14	eaglesnest															disappeared ... eaglesnest 50 km away mort / killed
15	P	78	0	P	78	0	P	78	0	P	78	0	P	78	0	d/s 35 km Parsnip 2km u/s Nov w /mort
16	hillside near P 74															d/s 38 km Parsnip hillside 1km from river mort / killed
17	P	90	0	P	90	0										d/s 20 km Table/Parsnip mort
18	P	31	0	P	31	0	P	31	0	P	31	0	P	31	0	d/s 92 km Parsnip mort
19	T	13		T	14	1	T	20	6	T	4	-16	P	58	-37	d/s 55 km late May Bills Ck/ Table July spawned
20	T	6	6	T	6	0	T	6	0	T	6	0	T	6	0	d/s 25 km Table mort
21	T	30	0	T	30	0	T	30	0	T	30	0	T	30	0	d/s 1 km mort
22				P	51		P	51	0	P	51	0	P	51	0	d/s 71 km Parsnip mort
23	T	26	-3	T	25	-1	T	22	-3	T	22	0	T	22	0	d/s 44 km Parsnip ..moved up April 30 spawned
24	T	20	3	T	21	1	T	11	-10	T	11	0	T	11	0	d/s 44 km Parsnip, up Ap 30. Par Table may 29 spawned
25																d/s 49 km Parsnip Sept disappeared disappeared
26	A	15	0	A	40	25	A	47	7	A	47	0	A	46	-1	d/s 40 km Anzac moved up May 29 spawned
27	A	2	-15	A	2	0	A	2	0	A	2	0	A	2	0	d/s 18 km Nov . d/s 12 km Apr. 30, d/s 15 Jul. 3 ?
28	A	3	0	A	3	0	A	29	26				A	47		d/s 54 km Parsnip Nov, up Apr. 30, Anz may 22 spawned
29	A	25	4	A	27	2	A	31	4	A	33	2	A	33	0	d/s 64 km Nov Parsnip Anzac May 22 spawned
30	P	63	0	P	63	0	P	63	0	P	63	0	P	63	0	d/s 44 km Nov Parsnip mort
31	A	33	9	A	42	9	A	42	0	A	42	0	A	8	-34	d/s 53 km Nov Anzac may 12 spawned
32	P	44	0	P	44	0	P	44	0	P	44	0	P	44	0	d/s 57 km Parsnip Sept mort
33	Res	0	0	Res	0	0	Res	0	0	Res	0	0	Res	0	0	d/s 101 km Sept Res.... swamp on east side mort / killed
34	A	33	21	A	38	5	A	38	0							d/s 64 km Nov, up May 12, mouth table May 29, Anz Ju spawned
35																d/s 67 km Nov, Res Dec. , April Pack, Jun. 19 gone disappeared
36																d/s 7 Sept Feb d/s 19 par Feb, up Apr. 30, Anz may 22 spawned
37	A	34	4							A	34		A	34	0	d/s 45 Par Nov, up may 12, Anzac June 6 spawned
38	P	39	0	P	39	0	P	39	0	P	39	0	P	39	0	d/s 59 Parsnip u/s 1 km mar 25 , d/s Apr. 30 ....mort? w/ mort
39	A	17	0	A	17	0	A	17	0	A	45	28	A	45	0	d/s 58 km Parsnip Nov, up Apr. 30, anzac may 22 spawned
40																d/s 47 Sept Parsnip ..... disappeared mar 25 disappeared
41	A	38	3	A	38	0	A	38	0	A	38	0	A	39	1	d/s 62 Nov Parsnip up Apr. 30 , anzac may 22 spawned
42	P	33	0	P	33	0	P	33	0	P	33	0	P	33	0	d/s 62 Sept Parsnip u/s 2 km Dec. 16 w/ mort
43	A	3	0	A	3	0	P	14	11	P	14	0	P	14	0	d/s 56 Nov Par u/s Jun. 6 past Anz, Anz Jun. 25 spawned
44	P	39	0	P	39	0	P	39	0	P	39	0	P	39	0	d/s 33 Dec. Anzac > Parsnip u/s 5 km Feb d/s April sp mort
45																d/s 59 km Nov Parsnip,u/s 11 km Dec., Res Apr. 30 disappeared
46	A	7	0	A	7	0	A	7	0	A	7	0	A	7	0	d/s 51 km Dec. Parsnip, up mar 25 , Anz Apr. 30 spawned
47																d/s 29 km Parsnip Sept disappeared
48	A	23	23	A	23	0	A	23	0	A	23	0	A	23	0	d/s 34 km Parsnip Dec. , Anzac May 22 spawned
49				A	22		A	42	20	A	46	4	A	46	0	d/s 46km up par3 Nov, up may 22 up 8 km , Anz July 9 spawned
50	P	22	0	P	22	0	P	22	0	P	22	0	P	22	0	d/s 86 km Parsnip Nov mort
51																d/s 8 Anzac Sept... gone... Apr. 30 res. poss mort disappeared
52	P	43	0	A	22	42	A	46	24	A	46	0	A	31	-15	d/s 60 km Par, Nov up past anzac may22, Anz July 9 spawned
53	P	60	0	P	60	0	P	60	0	P	60	0	P	60	0	u/s 1 km Sept/ d/s 48 Nov Parsnip w/mort
54	T	18	0	T	18	0										d/s 43 km Sept, up Apr. 16, table may 22,disap Jul. 24 spawned
55	A	39	0	A	39	0	A	39	0	A	39	0	A	39	0	d/s 4 km Sept mort

Code = Radio Tag #, R = River A-Anzac T- Table P- Parsnip Res- Reservoir km is the km on the river M =Distance traveled in km
M1 distance from Sept 19 to Sept 24 and MT total distance traveled to September 24
d/s downstream u/s up stream w/ mort died after upstream movement

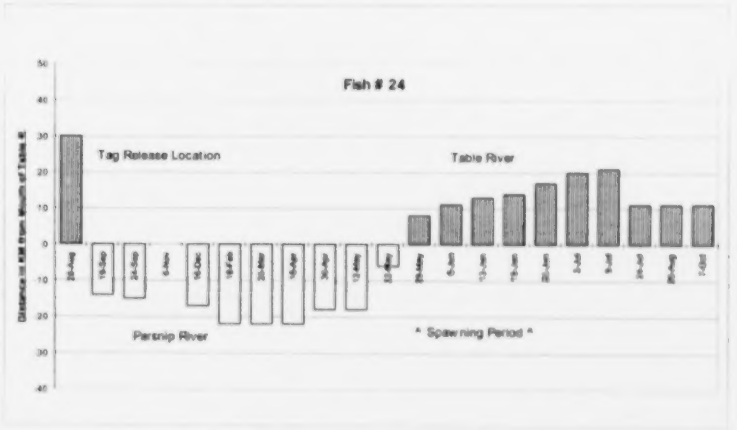
Appendix A Movements and locations of radio tagged Arctic grayling that returned to spawn.



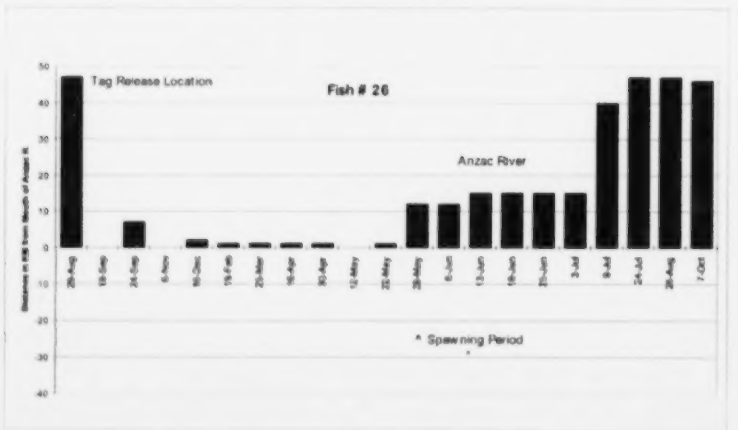
Arctic Grayling #19. Released August 28,1996 km 32 Table R. Male Fork Length 317 mm Weight 341 g Age 4



Arctic Grayling # 23 Released August 28 1996 km 30 Table R. Female Fork Length 340 mm Weight 419 g Age 5

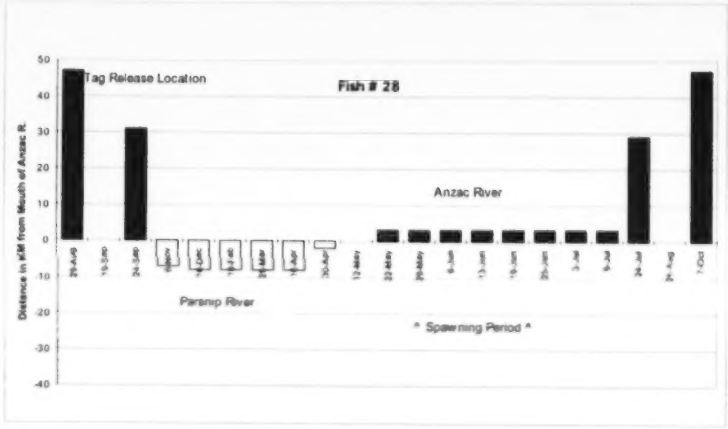


Arctic Grayling # 24 Released August 28 1996 km 30 Table River Female Fork Length 320 mm Weight 340 g Age 5

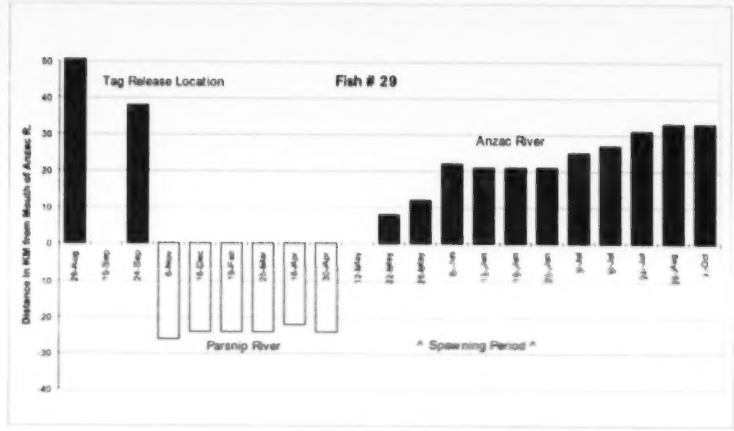


Arctic Grayling # 26 Released August 29 1996 km 47 Anzac R. Male Fork Length 378 mm Weight 504 g Age 6

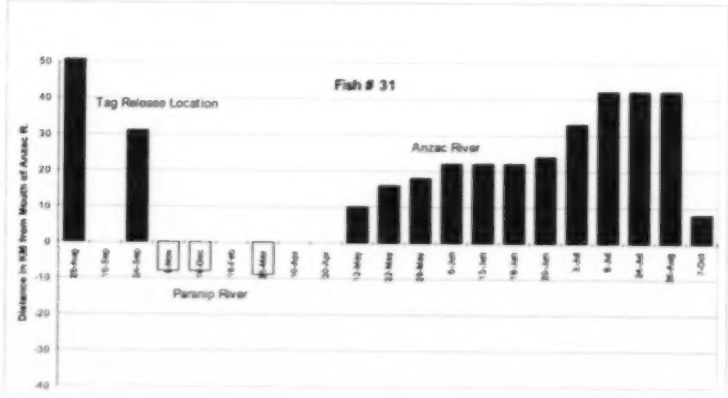
Appendix A cont.



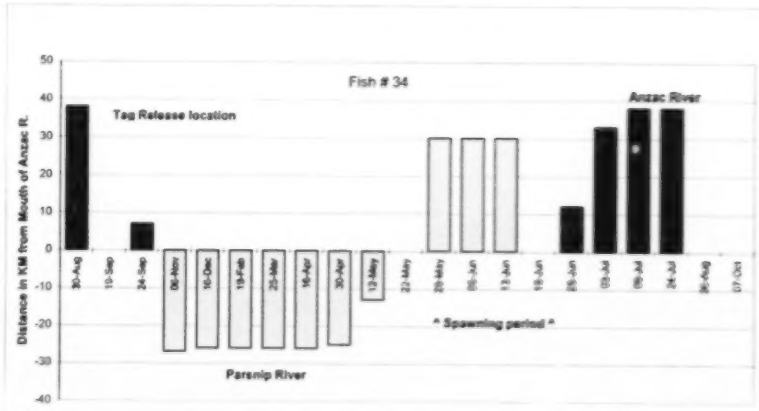
Arctic Grayling # 28 Released August 29,1996 km 47 Anzac River. Female Fork Length 320 mm Weight 373 g Age 6



Arctic grayling # 29 Released August 29, 1996 km 52 Anzac R. Female Fork Length 312 mm Weight 376g Age 4

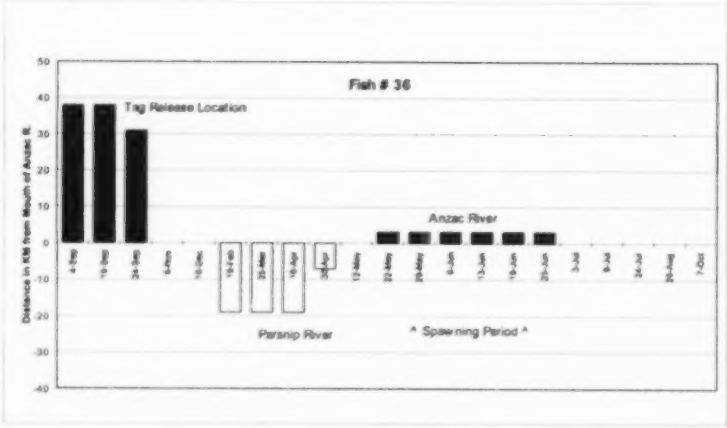


Arctic Grayling # 31 Released August 29, 1996 km 52 Anzac R. Male Fork Length 344 mm Weight 473 g Age 5

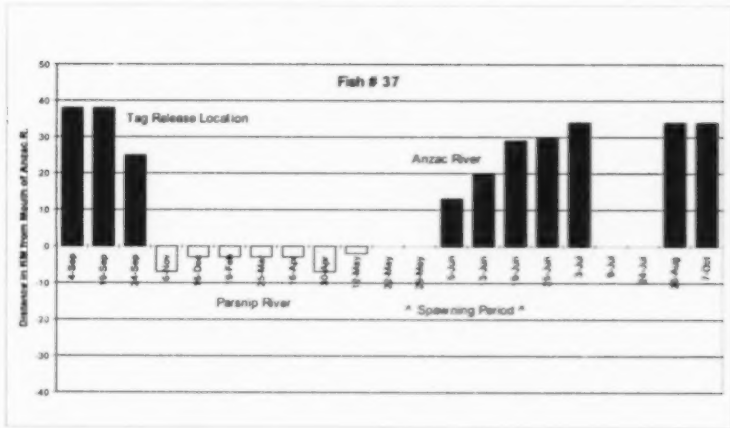


Arctic Grayling # 34 Released August 30, 1996 km 38 Anzac R. Male Fork Length 353 Weight 561 g Age 6

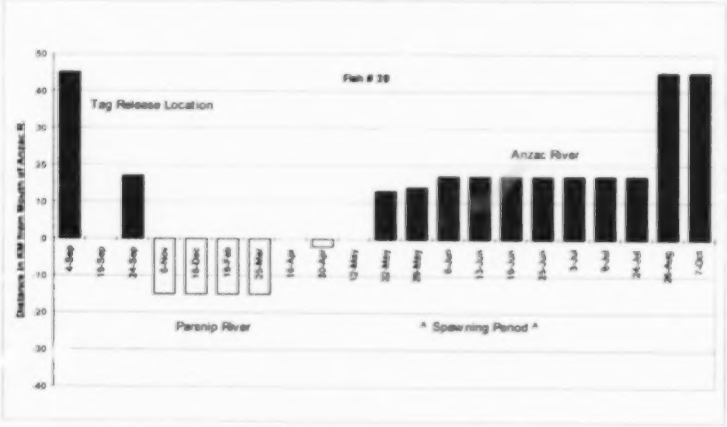
Appendix A Cont.



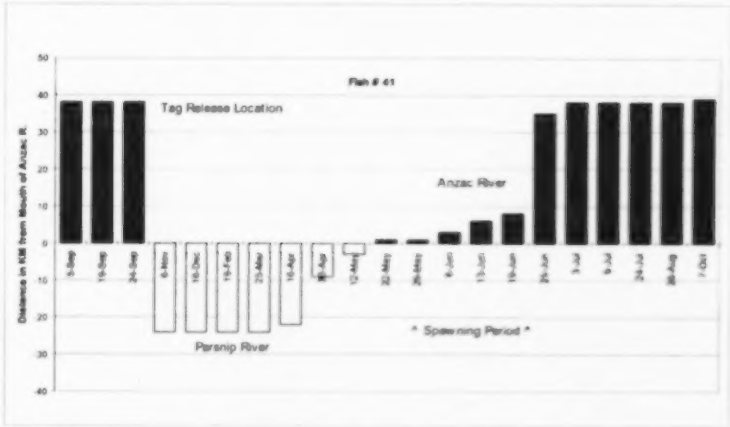
Arctic Grayling # 36 Released September 4,1996 km 38 Anzac R. Male Fork Length 370 mm Weight 504 g Age 5



Arctic Grayling # 37 Released September 4,1996 Anzac R. Female Fork Length 328 mm Weight 313 g Age 5

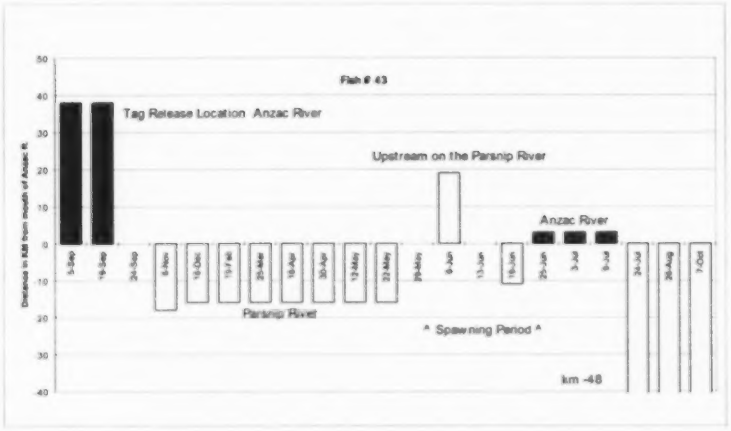


Arctic Grayling # 39 Released September 4,1996 km 45 Anzac R. Male Fork Length 328 mm Weight 378 g Age 5

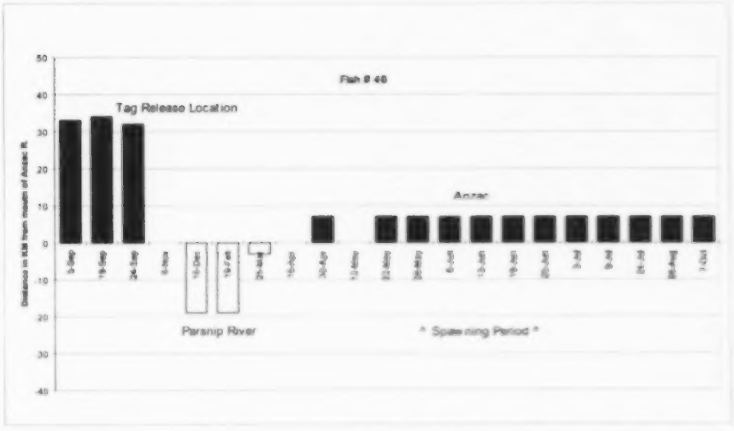


Arctic Grayling # 41 Released September 5,1996 km 38 Anzac R. Male Fork Length 378 mm Weight 610 g Age 7

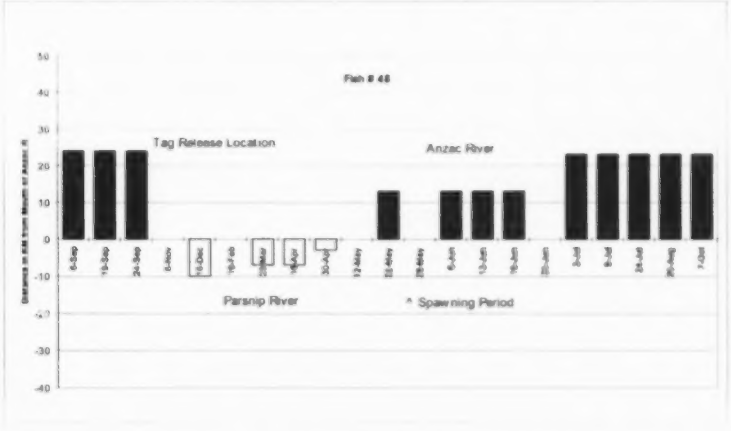
Appendix A cont.



Arctic Grayling #43 Released September 5,1996 km 38 Anzac R.
Female Fork Length 312 mm Weight 366 g Age 4



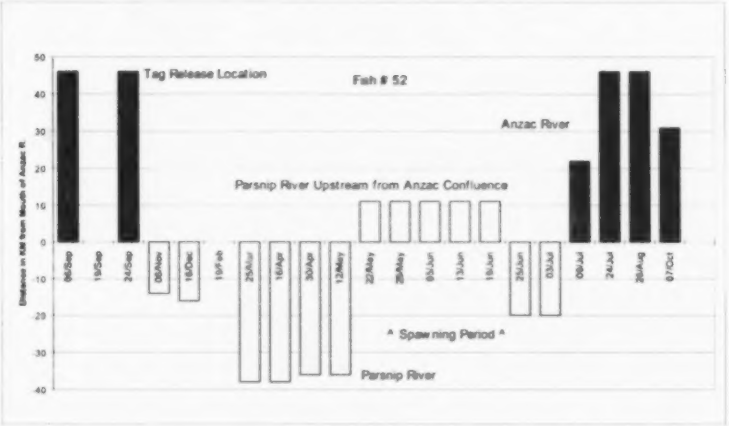
Arctic Grayling # 46 Released September 5 1996 km 33 Anzac R. Male
Fork Length 349 mm Weight 453 g Age 4



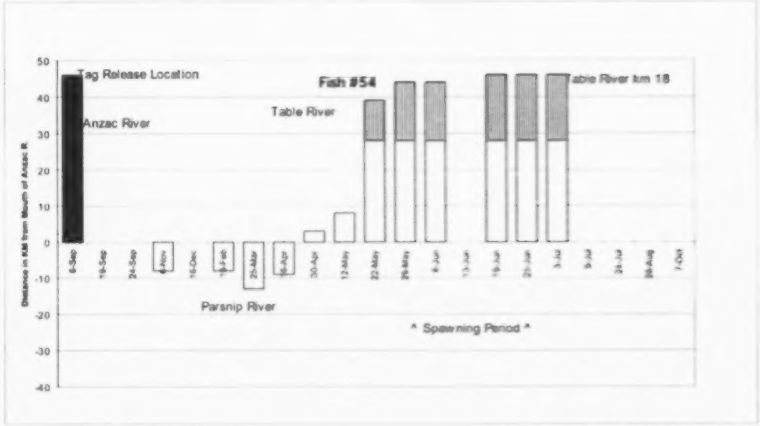
Arctic Grayling # 48 Released September 6,1996 km 24 Anzac R
Female Fork Length 325 mm Weight 368 g Age 5

Arctic Grayling # 49 Released September 6,1996 km 46 Anzac R. Male
Fork Length 349 mm Weight 467 g Age 6

Appendix A cont.



Arctic Grayling # 52 Released September 1996 km 46 Anzac R. Male
Fork Length 338 mm Weight 424 g Age 5



Arctic Grayling # 54 Released September 6,1996 km 46 Anzac R
Male Fork Length 333 mm Weight 428 g Age ?

Appendix B

Overwintering Habitats

OVERWINTER AREAS FOR ARCTIC GRAYLING

(all distance and depths are given in meters and velocities in mps)

FISH # 19 Long 122.251 Lat 54.720 300 m downstream from Anz km 68
30-Sep Substrate / gravel and fines bend below riffle and mid channel bar

Wetted Width	Thalweg Velocity	Thalweg Location	Depth (m) 0	10	20	30	40	50	60	70	80
			Distance from left bank								
74	1.4	60	0	-2.25	-1.9	-1.3	-1.15	-1.25	-1	-0.5	0
74	1.18	40	0	-2.2	-2.15	-1.75	-1.35	-1.05	-0.75	-0.35	0
72	1.3	40	0	-2.2	-2.3	-2	-1.45	-0.85	-0.6	-0.2	0
69	1.03	20	0	-1.7	-1.55	-1.65	-1.95	-1.35	-0.8	0	
66	**1.1**	**0**	**0**	**-1.45**	**-1.45**	**-1.85**	**-1.9**	**-1.4**	**-1.1**	**0**	
75	1.1	-20	0	-2.25	-2.4	-1.9	-1.5	-1.45	-0.85	-0.25	0
86	0.97	-40	0	-2.4	-2.4	-2.2	-1.9	-1.35	-0.85	-0.55	0
82	0.98	-60	0	-2.2	-2.6	-2.2	-1.7	-1.25	-1.05	-0.7	-0.15

X sectional Velocities
from right bank

Distance	depth (m)	Velocity surface	20cm
10	0.83	0.21	0.16
20	1.35	0.76	0.53
30	1.9	0.94	0.49
40	1.5	0.87	0.49
45	1.4	0.92	0.67
50	1.45	0.9	0.63
55	1.4	0.86	0.68
60	1.55	0.79	0.48
65	1.63	0.52	0.25

Fish # 24 Long 122.484 Lat 54.756 just below boat launch km 69
30-Sep Substrate cobble and gravel high velocity slot below a riffle

Wetted width	Thalweg Velocity	Thalweg Location	Depth (m) 0	10	20	30	40	50	60	70	80	90	100
			Distance from Left Bank										
131	1.29	60	0	0.3	1	1.75	0.7	0.3	0.35	0.3	0.15	0.15	1.13
120	1.46	40	0	0.3	1.25	2	0.95	0.35	0.2	0.07	0.2	0.6	0.9
117	1.27	20	0	0.1	0.48	1.9	2	0.7	0.2	0.05	0.1	0.45	0.7
113	**1.44**	**0**	**0**	**0.2**	**0.47**	**2.2**	**2.5**	**0.5**	**0.13**	**0.07**	**0.35**	**0.5**	**0.71**
105	1.6	-20	0	0.7	1.05	1.6	1.85	0.5	0.2	0.25	0.51	0.75	
102	1.44	-40	0	0.7	1.55	2	1.8	0.6	0.25	0.3	0.5	0.7	
100	1.3	-60	0	1.1	1.55	2.15	2.1	0.06	0.48	0.45	0.5	0.3	

X sectional Velocities
from left bank

Distance	Depth (m)	Velocity Surface	20 cm
10	0.17	0.14	
20	0.47	0.5	0.35
30	2.2	1.19	0.81
40	2.15	1.16	0.46
50	0.5	0.5	0.44
60	0.13	0.14	
70	0.07	0.09	
80	0.35	0.23	0.2
90	0.5	0.4	0.36
100	0.71	0.6	0.52

Fish # 49 Lat 122.513 Long 54.779 Between Anzac bridge and Anzac R km 66 Parsnip
01-Oct Substrate gravels and fines, some cobble in slot downstream from sharp bend

Wetted width	Thalweg Velocity	Thalweg Location	depth (m) 0	10	20	30	40	50	60	70	80	90
			distance from right bank									
92	0.76	80	0	2.4	2	1.25	2.5	2.3	2	1.85	1.25	0.3
87	1.14	60	0	2.2	1.35	1.3	2.4	2	1.45	1.65	1.25	0.2
84	0.76	40	0	3.5	2.8	2.7	1.9	1.8	1.45	1.7	1	0.25
87	0.92	20	0	2	3.2	2.5	2.2	1.85	1.75	1.6	0.95	0.27
95	**0.86**	**0**	**0**	**1.5**	**2.85**	**2.9**	**2.4**	**1.85**	**1.6**	**1.5**	**1.25**	**1**
90	0.8	-20	0	3.7	2.75	2.7	2.5	2.2	1.6	1.45	1.05	0.33
92	0.96	-40	0	3.5	2.45	2.55	2.5	2	1.6	1.25	1	0.32
96	0.85	-60	0	3.5	4	2.8	2.5	1.45	1.45	1.2	0.9	0.3

X sectional Velocities
from Right bank

Distance	Depth (m)	Velocity surface	20 cm
10	1.5	0.58	0.54
20	2.85	0.79	0.32
30	2.9	1.06	0.32
40	2.4	0.73	0.38
50	1.85	0.83	0.28
60	1.6	0.83	0.26
70	1.5	0.49	0.48
80	1.25	0.79	0.58
90	100	0.49	0.42

Fish # 26 Lat 122.527 Long 54.797 Lower Anzac R km 1
01-Oct Substrate cobble and gravel below riffle

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50
				distance from right bank					
55	0.81	40	60	0	0.6	1	1.7	2.4	1.8
56	0.9	40	40	0	0.5	1.35	1.9	2.2	1.35
56	1.05	48	20	0	0.6	1.2	1.9	1.95	1.4
54	**1.13**	**45**	**0**	**0**	**0.45**	**1.25**	**1.7**	**1.95**	**1.4**
54	0.95	45	-20	0	0.5	1.25	1.75	1.65	1.6
55	1.01	40	-40	0	0.4	1.1	1.45	1.5	1.8
55	1.03	30	-60	0	0.85	1.35	1.8	2	1.4

X sectional Velocities
from Right Bank

Distance	Depth (m)	Velocity surface	20 cm
10	0.45	0.41	0.28
20	1.25	0.76	0.59
30	1.7	1.15	0.67
40	1.95	1.05	0.65
50	1.4	0.62	0.7

Fish # 37 Lat 122.580 Long 54.827 Parsnip km 60
01-Oct Substrate gravel/ cobble strait section no unique characteristics

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	80
				distance from right bank								
88	1.34	13	75	0	2.7	2.8	2.5	2.4	2.1	1.8	1.45	0.9
86	1.36	18	50	0	2.4	2.5	2.7	2.4	1.85	7.5	1.25	0.85
88	1.25	7	25	0	2.35	2.15	1.9	1.65	1.35	1	1.21	0.61
104	**1.3**	**16**	**0**	**0**	**2.4**	**2.5**	**2.1**	**1.55**	**1.25**	**1**	**1.15**	**0.6**
103	1.52	8	-25	0	2.4	2.3	2.2	1.9	1.55	1.4	1	0.75
102	1.5	8	-50	0	2.2	2.4	2.45	2.25	1.9	1.75	1.3	0.95
106	1.43	10	-75	0	2.1	2.1	2.2	2.15	2.35	2	1.4	0.9

X sectional Velocities
from right bank

Distance	Depth (m)	Velocity surface	20 cm
10	2.4	1.35	0.63
20	2.5	1.43	0.74
30	2.1	1.01	0.67
40	1.55	1.35	0.76
50	1.25	1.29	0.68
60	1	1.22	0.57
70	1.15	1.38	0.82
80	0.6	1.2	0.98

Fish # 39 Lat 122.662 Long 54.902 Parsnip R km 48
02-Oct Substrate gravel cobble right channel by two islands

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	distance from right bank
58	1.03	20	100	0	1.5	1.35	1	1.4	1.15			
85	0.73	20	75	0	1.9	0.85	1.05	1.2	1.1	1	0.75	mid island channel
66	0.82	20	50	0	2.1	1.25	1.1	1.1	1.5			
66	1.03	20	25	0	1.9	1.5	1.2	1.2	1.45			
68	**1.1**	**20**	**0**	**0**	**2**	**1.3**	**1**	**1.05**	**1.45**			
62	1.01	20	-25	0	1.75	1.4	1.15	1.1	1.25			
64	1.04	20	-50	0	1.8	1.65	1.2	1	1.2			

X sectional Velocities from right bank

Distance	Depth (m)	Velocity surface	20 cm
10	2	0.96	0.45
20	1.3	1.1	0.72
30	1	0.98	0.65
40	1.05	1.01	0.5
50	1.45	0.9	0.53

Fish # 43 Lat 122.663 Long 54.901 Parsnip km 47
02-Oct Substrate cobble boulder Left channel two islands upstream one below shallow riffle on right

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	80	90	distance from left bank
66			200	0	1.7	2.4	2.3	2.4	2.45	2.4	island			
70			150	0	1.9	2.5	2.4	2.35	2.3	1.9	island			
135			100	0	1.8	1.95	1.9	1.85	2	18	1.5	1.7	1.8	1.9
135			75	0	1.6	1.7	1.7	1.75	1.85	1.7				
137			50	0	1.25	1.5	1.55	1.45	1.6	1.7				
152			25	0	1.2	1.05	1.2	1.2						
132			**0**	**0**	**1.3**	**1.05**	**0.4**		**shallow riffle**					
127			-25	0	1.7	0.85	0.7							
110			-50	0	2.1	0.95	0.65	island / bar						

X sectional Velocities from left bank

Distance	Depth (m)	Velocity surface	20 cm
10	1.3	1.26	0.52
20	1.05	0.56	0.25
30	0.4	fast shallow riffle	

Fish # 54 Lat 122.602 Long 54.844 km 55 Parsnip R near fish # 28 & 30
01-Oct

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	80	90	distance from left bank
100	no		75	0	1.6	1.9	2.35	2.4	2.35	2	1.6	1.3	0.95	
101	thalweg		50	0	1.65	2.1	2.25	2.4	2.25	1.9	1.5	1.25	1.15	
104			25	0	1.75	1.75	2.25	2.4	2	1.7	1.2	1	1	
100	even	velocity	0	0	1.7	1.8	2.3	2.3	1.7	1.6	1.25	1.1	0.95	
110			-25	0	1.3	1.25	2.4	2.2	2.2	2.45	1.15	1	0.9	
110			-50	0	1.45	1.9	2.3	2.35	2.1	1.5	1.2	1.1	0.85	
120			-75	0	1.25	1.55	2	2.4	2.2	1.3	1.2	0.8	0.7	

X sectional Velocities from left bank

Distance	Depth (m)	Velocity surface	20 cm
10	1.7	1.3	0.72
20	1.8	1.34	0.62
30	2.3	1.4	0.58
40	2.3	1.28	0.71
50	1.7	1.29	0.65
60	1.6	1.42	0.6
70	1.25	1.3	0.6
80	1.1	1.11	0.71
90	0.95	1.03	0.61

Fish # 36 Lat 122.685 Long 54.915 Parsnip R km 44
02-Oct

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	80	90	100	110	Distance from right bank
118			50	0	1.25	1.7	1.9	1.95	1.8	1.75	1.8	1.8	1.8	2	1.5	
118	no		25	0	105	1.5	1.7	1.9	1.9	1.9	1.75	1.7	1	2.15	1.45	
120	thalweg		**0**	**0**	**0.9**	**1.4**	**1.6**	**1.9**	**2**	**1.9**	**1.6**	**1.5**	**1.6**	**1.9**	2	
114			-25	0	1	1.4	1.8	1.9	1.9	1.8	1.75	1.6	1.6	2	1.9	
112			-50	0	1.7	1.9	2.1	2.3	2.35	2.15	1.95	1.9	2.3	2.7		
112			-75	0	1.6	1.6	1.75	2.1	2.1	2.1	1.8	1.65	2.1	2.5		

X sectional Velocities from right bank

Distance	Depth (m)	Velocity surface	20 cm
10	0.9	1.24	0.7
20	1.4	1.39	0.74
30	1.6	1.32	0.52
40	1.9	1.49	0.55
50	2	1.46	0.44
60	1.9	1.28	0.53
70	1.6	1.33	0.68
80	1.5	1.35	0.65
90	1.6	1.3	0.66
100	1.9	1.35	0.41
110	2	1.31	0.48

Fish # 46 Lat 122.695 Long 54.924 km 44 Parsnip
02-Oct Substrate cobble boulder upstream from riffle and side debris jam

Wetted width	Thalweg Velocity	Thalweg Location	Location	depth (m) 0	10	20	30	40	50	60	70	80	90	distance from right bank
101			75	0	1.8	2.45	2.7	2.45	2.25	2.1	2	1.7	1.4	
		Even	50	0	1.25	1.85	2	2.4	2.2	2.2	1.9	1.7	1.55	
		flow	25	0	1.4	1.75	1.8	2.35	2.4	2.3	2	1.7	1.1	
			0	**0**	**0.9**	**1.25**	**1.9**	**2.35**	**2.4**	**2.25**	**1.95**	**1.6**	**1.5**	
111			-25	0	1.15	1.6	2.1	2.35	2.3	2.3	2.05	1.7	1.25	
			-50	0	1.4	1.8	2.25	2.35	2.35	2.05	1.9	1.6	1.15	

Fish Latitude, Latitude, location Wetted Width in meters, Thalweg velocity surface in m/s Thalweg Location distance in m from bank, Location distance in m upstream or -down from the fish location, velocities measured at the surface and 20 cm above bottom
X sectional velocities measure at the location of the fish

Appendix C

Radio Tracking Problems

For the most part the radio tracking went smoothly, but it was very difficult to cover the entire area in one day (approximately 180 km of river). Reception distances were highly variable ranging from a few hundred meters up to 10 kilometres, and this appeared to change with the weather. High voltage electrical transmission lines caused interference problems and on one occasion the survey had to be repeated the following day because of high interference along a 10 km stretch of the river (just prior to a snow storm). It was possible to pinpoint the location of many tags to within a small (20 m) area, other tags were difficult to locate with 100 m and occasionally only weak signals were received. In which case location accuracy could have been off as much as several kilometres. These weak signals were attributed to the topography, which could block direct signals, or bounce them off hills and confuse reception.

There were difficulties separating individual codes on the same frequency. If several tags on the same frequency were at the same location the receiver operator could hear the different signals but only one was displayed on the receiver. All tags would eventually be displayed because the codes were set at slightly different intervals. However, locating a tag was complicated because the receiver display could move to a second code before the first tag location was pinpointed. Stronger signals were received from some tags, making it more difficult to track weaker signals on the same frequency. If the receiver operator isolated a frequency too soon it was possible to overfly a weak signal on one frequency, while tracking a strong signal on another frequency. It was also often hard to determine if a weak signal (no code or signal strength) was a fish that had just been located and was behind the helicopter, or if it was a new signal in front. Some of these problems could have been reduced by using multiple receiving units set on individual frequencies.

In order to extend battery life, the tags were programmed to transmit once every five seconds and for eight hours per day. This made it more time consuming to pinpoint tag locations because transmissions were five seconds apart and it was necessary to scan each frequency for slightly more than five seconds. This made it necessary to have multiple tags (13-14) on one frequency (scanning 55 frequencies for five seconds would require too much time given helicopter travel speeds). Battery power was also saved by having the tags shut off for 16 hours a day, but this made it very difficult to cover the entire area during an eight hour period. There was also a small amount of drift in the transmitting times and some tags were off by up to one hour, further reducing the amount of time available for tracking.

The main spawning areas were surveyed first (starting at 09:30 A.M.) to ensure these areas were thoroughly covered. This may have been a possible reason why the grayling were located in deep pools rather than in potential spawning areas during the surveys. Most spawning occurs in mid to late afternoon (Beauchamp 1990, Van 1964). Female grayling hold in deep pools and only enter the spawning grounds for short periods (Tack 1971; Beauchamp 1990). The males remain on the spawning grounds defending their territories throughout the spawning period or may retreat to deep pools during the evening and return to the spawning grounds the next day (Rawson 1950; Tack 1971; Kraft and Smith 1980; Beauchamp 1990). It would be advisable, in the future to have the tags programmed to transmit for ten to twelve hours per day during the spawning period to allow surveys to be conducted later in the day and to cover a greater area. Operating in a smaller geographic area does not appear to be an option with this species, as fish tagged in the same pool could easily be well over 100 km apart during the spawning period.